APPLIED MECHANICS Reviews

A CRITICAL REVIEW OF THE WORLD LITERATURE IN APPLIED MECHANICS AND RELATED ENGINEERING SCIENCE

REVS. 5541-6137 VOL. 13, NO. 11 NOVEMBER 1960

APPLIED MECHANICS Reviews

Published Monthly by THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at Easton, Pa., and edited by Southwest Research Institute with the co-operation of Linda Hall Library.

Under the Sponsorship of

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

THE ENGINEERING FOUNDATION

SOUTHWEST RESEARCH INSTITUTE

OFFICE OF NAVAL RESEARCH

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (ARDC)

NATIONAL SCIENCE FOUNDATION

Industrial Subscribers

AMERICAN MACHINE AND FOUNDRY COMPANY

THE BABCOCK & WILCOX COMPANY

CATERPILLAR TRACTOR COMPANY

FORD MOTOR COMPANY

GENERAL DYNAMICS CORPORATION

GENERAL MOTORS CORPORATION

M. W. KELLOGG COMPANY

SHELL DEVELOPMENT COMPANY

STANDARD OIL FOUNDATION, INC.

UNION CARBIDE CORPORATION

UNITED AIRCRAFT CORPORATION

UNITED SHOE MACHINERY CORPORATION

WESTINGHOUSE ELECTRIC CORPORATION

WOODWARD GOVERNOR COMPANY

APPLIED MECHANICS REVIEWS, November 1960, Vol. 13, No. 11. Published Monthly by The American Society of Mechanical Engineers at 20th and Northampton Streets, Easton, Pa., U. S. A. The editorial office is located at the Southwest Research Institute, San Antonio 6, Texas, U. S. A. Headquarters of ASME, 29 West 39th St., New York 18, N. Y., U. S. A. Price $2.50 per copy, $25.00 a year. Changes of address must be received at Society headquarters seven weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-laws: The Society shall not be responsible for statements or opinions advanced in papers or printed in its publications (B13, Par. 4). . . . Entered as second-class matter, January 11, 1948, at the Post Office at Easton, Pa., under the Act of March 3, 1897.

HOW TO OBTAIN COPIES OF ARTICLES INDEXED: See section after Books Received for Review.

Editorial Office: **APPLIED MECHANICS REVIEWS, Southwest Research Institute, 8500 Culebra Road, San Antonio 6, Texas, U. S. A.**
Subscription and Production Office: **The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., U. S. A.**
Depository: **Linda Hall Library, 5109 Cherry Street, Kansas City, Missouri**

APPLIED MECHANICS REVIEWS

VOL. 13, NO. 11 NOVEMBER 1960

MECHANICAL WEAR

G.W. ROWE

Tube Investments Research Laboratories,
Hinxton Hall, Cambridge, England

1. INTRODUCTION

Wear is almost universally regarded as undesirable, yet it is encountered wherever there is sliding contact, from the pocket watch which runs accurately for years, to the engine which wears out in hours on a sandy airstrip. It is often forgotten that steady wear can be useful, for example, when an engine is run-in. Even the pencil used to write this article relies on a steady wear process. It is significant that the word "friction" has its antithesis "lubrication," but "wear" has no positive antonym.

Except for corrosive and erosive loss, wear is generally associated with sliding and is usually detected by loss of material from one or both of the surfaces in contact. The material may merely be displaced by plastic deformation, it may be transferred from one surface to the other, or it may be removed entirely from the surfaces. There are usually several interacting chemical, mechanical and physical factors in the wear process, which may be either steady, even though severe, or sudden and catastrophic. To restrict the scope of the term "wear" two definitions have been proposed: The Institution of Mechanical Engineers (1) has defined mechanical wear as the progressive loss of substance from the surface of a body brought about by mechanical action. They further comment that wear usually reduces the serviceability of a body, but can be beneficial in the initial stages of running-in. The German Standards Institute has defined the technical term "wear" as the undesirable change of the surface of practical objects owing to the separation of small particles, resulting from mechanical causes (2).

2. PRINCIPLES OF WEAR TESTING

Wear is essentially manifested either by change in size or by weight loss. Often a simple measurement of a dimension, such as the diameter of an engine cylinder, is sufficient to assess the wear. This is particularly valuable in field trials and many of these have been reported; see for example ref. 3. Perhaps the most carefully controlled and comprehensive tests of this type are those described by Lees (4) in which a statistical investigation of cylinder wear in marine diesel engines was undertaken with a fleet of 33 ships for a period of years. Such a study is naturally outside the scope of normal laboratory experiments and for more detailed study of wear, special apparatus has usually been constructed. A common type, known as the four-ball apparatus, uses a rotating ball nesting on three contiguous balls. Three wear scars are produced in the stationary balls and a ring of damage appears on the rotating one. The scars may be measured optically, or the weight loss may be determined, directly or by a chemical assessment. A different arrangement often used, produces a wear scar on the rounded end of a pin held in contact with a rotating plate. In recent years radio-isotopes have provided a greatly increased sensitivity for such measurements. It is sometimes important to examine the wear due to a single traversal, in which the wear debris does not complicate the results. Then the pin may be traversed over a fresh surface in a spiral sliding track, in a modification of the second type of apparatus, instead of the usual circle, or a helical track may be followed on the surface of a cylinder. A further refinement, required to examine the initiation of wear, uses a stationary cylinder which is traversed across and along a rotating cylinder, so that no element of either surface is subjected to contact more than once. A change in the direction of sliding can also influence wear by disturbing the orientation of the wear debris. To study these conditions, a reciprocating test apparatus is used. Yet another combination, intended to simulate gear tooth contact, uses two discs in edge contact with differing peripheral speeds.

These principles have been embodied in a number of commercially available wear testing machines, but unfortunately the results obtained often differ according to the machine used. They cannot be transferred directly to industrial practice.

3. SELECTED EXPERIMENTAL INVESTIGATIONS

Even in 1957 (2) there were over 20,000 papers referring to wear. Fortunately for the reviewer most of these are believed to refer to specific topics related to particular applications, but even so, the selection of a few experimental studies is inevitably personal and arbitrary. A few recent experiments of a simple illustrative character are discussed here in some detail.

3.1. Dry sliding

Lack of reproducibility has always been a serious handicap to wear experiments, but Archard and Hirst (5) found that with a pin and ring apparatus it was possible to obtain consistent results after an initial transitional period. For a wide range of material combinations, speeds and loads, the volume of material removed was directly proportional to the distance of sliding, but this rate of wear varied from 0.03×10^{-10} cm^3/cm for a sintered tungsten carbide pair to $1{,}570 \times 10^{-10}$ for a mild steel pair. The rates were however independent of the apparent area

of contact of the sliders. A striking feature of the experiments, in accordance with earlier observations, is that at light loads a mild form of wear is observed, but after running under heavy loads a patch of more severe damage may be initiated, which subsequently spreads, giving a severe form of wear and extensive metallic contact. Archard and Hirst found that for both forms of wear the volume removed is proportional to the sliding distance.

The mild wear process has been studied in more detail by Kerridge (6) using a radioactive annealed tool steel pin against a hardened tool steel ring. Radioactive pin material was transferred to the ring until an equilibrium amount was built up. When the active pin was replaced by an inactive one, the amount of transferred radioactive material on the ring decreased, but none was transferred back to the pin. This suggests a two-stage process of wear in which the pin material is first transferred to the ring as a layer from which the wear debris eventually comes. This type of behavior has also been observed for the severe wear conditions using soft brass on a hard steel ring (7).

In a study of single-traversal sliding, Golden and Rowe (8) used a radioactive tungsten carbide pin sliding on a copper disc. The tungsten carbide transferred steadily to the copper and remained strongly attached to it. On the other hand, reciprocating sliding gave a greatly increased wear in which the debris was loosely scattered. The tungsten carbide particles deposited in the first traversal abraded away further tungsten carbide. The steady transfer rate was about 1.2×10^{-10} cm^3/cm. Autoradiographs show this to be smooth within the resolution of the photographic film, about 1–2 microns. They also followed the reverse process, using a radioactive copper disc and an inactive tungsten carbide slider (9). The amount of copper transferred to the carbide increased rapidly within about two millimeters of sliding to a steady equilibrium value. Thereafter copper transferred continuously to the tungsten carbide and back to the copper track, a complete exchange being effected in about 2 mm of sliding. This transferance resembles that found for brass to steel by Kerridge during repeated sliding, but is on a much smaller scale. The equilibrium amount of copper was about 20×10^{-6} gm compared with 2×10^{-3} gms and was achieved in about 2 mm compared with about 10 meters.

Steijn (10) used two rotating rings in facial contact. This also showed an equilibrium process, with some back transferance. Both Steijn and Kerridge found that the eventual production of loose wear particles in multiple sliding depended on the possibility of the transferred material oxidizing. The important influence of atmosphere on dry sliding has been examined by many earlier workers.

3.2. Lubricated sliding

When a lubricant is present the areas of metallic contact are drastically reduced and the wear rate falls markedly (11). However, in the presence of a lubricant, it appears to be even more difficult to obtain reproducible experimental results. With some lubricants, chemical attack of the sliders may be important and several workers have reported that oleic acid, a good boundary lubricant, may increase the wear rate. The supposition is that the boundary additive attacks the surface to form a low-friction film which is then readily sheared away, leaving fresh metal for a further film to reform. Corrosive elements such as chlorine and sulphur, often added for "extreme-pressure" protection against seizure, can also cause severe wear under unfavorable conditions. Oxygen and water vapor in the atmosphere may also play a significant role. Grunberg and Campbell (12) have demonstrated that the transfer of copper to steel under boundary-lubricated conditions depends greatly on the surface roughness of steel. Golden and Rowe (8) have shown that the roughness of a soft material such as copper can considerably influence the wear rate, even of tungsten carbide. Good surface preparation and close attention to lubricating conditions is essential if reproducible results are to be obtained.

4. THEORIES AND LAWS OF WEAR

Wear is often a random phenomenon, depending on fragments of abrasive from the environment, but careful laboratory experiments (5, 8, 10) suggest that mechanical wear can be a reproducible phenomenon suitable for detailed study. This has led to the formulation of a number of algebraic equations, or laws of wear.

4.1. Dry wear theories

Holm has considered wear on the smallest possible scale, resulting from encounters between individual atoms (13). If the atomic spacing is (α) each atom in the load-bearing area (A) will encounter s/α atoms of the opposing face, while sliding a distance (s). The total number (N) of encounters by all the atoms in the area (A) will thus, neglecting other interactions, be

$$N = \frac{s}{\alpha} \cdot \frac{A}{\alpha^2} \qquad [1]$$

If we postulate a probability (k) of an atom being removed by such an encounter, for example by shearing, or by a cutting action if one surface is much harder than the other, the total volume (V) removed by wear is

$$V = k \cdot N \cdot \alpha^3 = k \cdot s \cdot A. \qquad [2]$$

Now according to the theory of unlubricated or boundary friction (14) the real load-bearing area (A) is independent of the nominal contact area and is determined by the applied load (W) and the yield pressure (p). The surface asperities deform plastically until the true contact area is just sufficient to support the load at the yield pressure

$$W = A \cdot p. \qquad [3]$$

There is adhesion between the surfaces at these asperity junctions and the force required to shear them is found to be the major part of the frictional resistance. It is assumed that these junctions also contribute the wear particles. Combining equations [2] and [3], we have a general wear equation

$$V = \frac{k \cdot s \cdot W}{p}. \qquad [4]$$

In the majority of experiments the wear is not of a single atomic nature, but Archard (15) has shown that a similar equation can be deduced on the assumption that the unit encounter is between two surface asperities, rather than between individual atoms. He supposes wear to occur at localized regions of mean radius a, reaching completion in a sliding distance $2a$. It is further assumed that the volume of the wear particle is proportional to a^3, justified experimentally in preference to the assumption of layer removal which would be proportional to a^2. The wear rate, or volume worn per unit distance, due to the single region of real contact is thus proportional to a^2, that is to the area of a single contact. The total wear is then found by summation, using the relation between load and contact area of equation [3] above. Archard finds

$$\frac{V}{s} \propto \sum \frac{a^2}{2a} \propto \frac{W}{p}. \qquad [5]$$

He also deduces equations for elastic contact, leading to a slightly lower index of W. Equation [5] is the same as equation [4] above. Burwell and Strang (16) have deduced a similar equation semi-empirically. Two laws of wear can be stated from this equation:

(1) the volume of worn material is proportional to the sliding distance.

(2) the volume of worn material is proportional to the load.

The first law is supported by a considerable amount of evidence (for example references 5, 8, 10, and 16), and has indeed become accepted in the term "wear rate" defined as volume worn per unit sliding distance. The second law is also experimentally verified providing that the surface conditions are not materially changed by the change in load. Thus, for example, the wear rate is proportional to the load in a mild wear regime (6) and is again proportional but with a different constant after the load has caused a transition to severe wear (7).

The derivations of the formula assume that the contact area (A) is the real metallic contact. This assumption is basic in the theory of friction, in which the frictional resistance (F) of unlubricated or boundary-lubricated surfaces is determined by the shear strength (σ) of these junctions. Thus

$$F = \sigma A = \sigma \frac{W}{p} \quad \text{or} \quad F = \mu W \qquad [6]$$

There is a considerable amount of evidence to show that the coefficient of friction (μ) is indeed independent of the apparent contact area. It has also been found (5) that the wear rate is independent of the apparent contact area. Although equations [4] and [6] show similarity, there is an important difference. The coefficient of friction of dry, clean metal surfaces may lie between 0.5 and 1.5, and this can be reduced to about $\mu = 0.1$ with good boundary lubricants (14). On the other hand, the values of the wear constant (k) may vary (5) from 10^{-2} to 10^{-7}. It must be supposed that whereas all junctions contribute to friction, only a few (k) contribute to wear. Rabinowicz and Tabor (11) have confirmed that small changes in surface conditions produce a large change in wear with a relatively small change in friction.

4.2. Interpretation of the probability factor (k)

Holm (13) suggested (p. 215) an interpretation of (k) in terms of molecular layers. If the wear is strictly uniform over the area (A) and z atomic layers are removed, the volume of material removed will be

$$V = z \cdot \alpha \cdot A \qquad [7]$$

supposing the atomic spacing to be (α). From the electrical contact measurements, Holm has concluded that the average asperity contact has a radius of about $a = 10^{-3}$ cm. Thus for a complete passage of one such contact, the distance (s) in equation [2] may be taken as 2×10^{-3} cm. Thus $V = k \times 2 \times 10^{-3} \times A = z \cdot \alpha \cdot A$. For the present purpose we may take α as about 2×10^{-8} cm, giving $z = 10^{5} \cdot k$. Holm found certain examples of atomic or amorphous wear in which z is of the order of unity ($k = 10^{-5}$), notably for metals with monomolecular lubricant films. More commonly he found z between 1 and 10, but for some combinations, particularly when both sliders are made of the same metal, z could exceed 1000, implying a value of k exceeding 1%. All his experiments used sliders which had been adequately run-in. Golden and Rowe (8) found that during a single traversal of tungsten carbide on copper the average thickness of the transferred layer was about 6 Ångstroms, approaching $z = 1$. However, under most conditions the transference is visibly in quite large fragments.

4.3. Variability of (k)

The form of equation [4] is supported by experimental evidence for surfaces which have been well run in, for surfaces which have been carefully prepared and then traversed once only, for grinding wheels, and for wear attributable to extraneous abrasive. Under all these widely different conditions, the nature of the sliding surfaces is not appreciably altered by the wear process itself. Sometimes however, as wear occurs, it makes further wear less likely. This is found, for example, during running-in when the surfaces slowly come to greater conformity, the wear being contributed mainly by the asperity peaks. On the other hand the wear particles may be highly abrasive, as can occur, for example, when the wear debris from steel surfaces is permitted to oxidize. It also occurred in Golden and Rowe's experiments (8) in which tungsten carbide particles became embedded in the copper surface and caused abrasive wear during the second traversal. Three equations to cover these three types of wear have been proposed by Barwell (17).

When the metals are soft it has been shown (14) that the contact area is determined not by the normal pressure alone but by the combined frictional and normal loads. This causes the contact area to increase during sliding, accompanied by an increase in the wear rate $\frac{V}{s}$. This can be prevented by adequate lubrication.

Departure from equation [4] can also occur when the surfaces are deformed elastically. Then the true area of contact is no longer directly proportional to the load. For a single spherical elastic contact $A \propto W^{2/3}$. From this we can deduce that $F \propto W^{2/3}$ and Amontons law, that $F \propto W$, should not be obeyed. This is confirmed by experiments with diamond sliders. However, Archard (18) has shown that for multiple contacts the index of W increases as the number of contacts increases, and tends to unity.

In a study of the resistance of metals to wear by abrasion, Khruschov (19) found an inverse relationship between the worn volume and the hardness of the metal rubbed against an abrasive cloth. This accords with the third aspect of equation [4].

5. CORROSIVE WEAR AND THE INFLUENCE OF TEMPERATURE

Most metals have a thin protective film of natural oxide which may be relatively wear resistant but is eventually worn away, exposing bare metal to corrosive attack. Fretting is a well-known example of such a sequence of mild atmospheric corrosion followed by rubbing wear and further corrosion, in which the final product is brown iron oxide. When the product is itself abrasive wear is accelerated, and iron oxide scale or rust frequently causes serious trouble. Many lubricants are mildly corrosive, especially in the presence of oxygen and water, but more serious attack may occur for example when acidic vapors from combustion condense on the cold cylinder walls of an automobile engine. On the other hand it is possible for steel to be nitrided in air at the high temperatures generated locally during sliding, forming a hard wear-resistant skin (20).

Certain other beneficial surface films, such as NiO on Ni, can be formed during sliding at high temperatures (21).

An interesting example of high-temperature corrosive wear has been investigated by Trent (22). He found that the cratering which occurred during high-speed cutting of steel with tungsten carbide tools was attributable to the formation of a liquid-phase alloy at about 1,300°C. This alloy did not form with a tungsten/titanium mixed carbide, which showed a much lower wear rate under these conditions. Diamonds are susceptible to oxidative wear at high temperature in air, but Scott (23) has shown that at high temperatures in nitrogen the wear of diamond may be due to thermal degradation to amorphous carbon. Apart from these rather unusual effects, the temperature can of course play a major part in causing breakdown of lubricant.

An ingenious application of high-temperature wear which has been suggested recently is to provide transient gas lubrication for very high-speed passage through the atmosphere by allowing the solid surface to volatilize.

6. WEAR PREVENTION OR REDUCTION

The earliest known example of deliberate wear reduction is recorded by Davison (24) who shows a picture of an Egyptian drill dated about 1450 B.C. in which a stone bearing cup has been used instead of a wooden one. He also comments that chariot bearings were protected from sand and dust by leather coatings. Even today, there is little doubt that the best way to prevent wear is to maintain an adequate film of lubricant between the surfaces so that solid contact is avoided. In many machines this can be done by proper design of bearings to provide hydrodynamic lubrication. Where this is not possible, finely divided soft solids may be added to the lubricant. Graphite and molybdenum disulphide are often used. Under boundary-lubrication conditions some wear will always occur, though the amount may be made negligibly small.

Abrasive wear accounts for a large fraction of the total wastage of time and material due to wear. It is therefore essential to ensure wherever possible that dust and grit are excluded. Corrosion may also be important, and it should be borne in mind that not only atmospheric constituents but also otherwise desirable ingredients of lubricants may have to be excluded where there is a danger of corrosion or fretting. If corrosion products are inevitable, it may at least be possible to select the materials so that these are not of an abrasive character. The surfaces should be smooth to prevent scoring, but if the contact is too intimate the danger of seizure may be increased.

When these design features have been considered, it may still be possible to choose the materials and surfaces, so that wear is reduced under boundary-lubrication conditions or even when the boundary lubrication may break down. Hard chromium plating, case-hardening, or bulk-hardening may be used to prolong the life of one component relative to the other, but care should be taken to avoid brittle asperities which might lead to abrasive wear. This is particularly important when hard ceramics are used. Useful short-term protection of steel surfaces may be provided by chemical coatings, for example by phosphating or treatment with graphite or molybdenum disulphide. Other films, such as iron chloride, give a low friction but in doing so wear away rapidly.

In conclusion it may be said that the fundamentals of wear are still not fully understood and much research remains to be done to isolate and study in detail many interacting factors. The best protection is still, as in the days of the Pharoahs, to provide adequate lubrication and exclude grit.

ACKNOWLEDGEMENT

This paper has been prepared by permission of the Chairman of Tube Investments Ltd.

REFERENCES

1 Instn. Mech. Engrs. (1957), Conf. Lubrication and Wear—Definitions.

2 Wahl, H., *Wear* **1,** 3, 212–224, 1958.

3 Rosen, C. G. A. (1950), A. S. M. Conf. Mechanical Wear, pp. 8–16.

Lane, P. S. (1950), A. S. M. Conf. Mechanical Wear, pp. 17–45.

4 Lees, H. D., *Wear* **2,** 4, 273–295, 1958.

5 Archard, J. F., and W. Hirst, *Proc. Roy. Soc. Lond.* (*A*) **236,** 397–410, 1956.

6 Kerridge, M., *Proc. Phys. Soc. Lond.* (*B*) **58,** 400–407, 1955.

7 Kerridge, M., and J. K. Lancaster, *Proc. Roy. Soc. Lond.* (*A*) **236,** 250–264, 1956.

8 Golden, J., and G. W. Rowe (1958), UNESCO Conf. Radioisotopes, Paris, pp. 343–357; *Brit. J. Appl. Phys.* **9,** 120–121, 1958.

9 Golden, J., and G. W. Rowe, *Brit. J. Appl. Phys.* **10,** 367–371, 1959.

10 Steijn, R. P. (1958), Trans. ASME Pap. 58-LUB-8.

11 Rabinowicz, E., and D. Tabor, *Proc. Roy. Soc. Lond.* (*A*) **208,** 455–475, 1951.

12 Grunberg, L., and R. B. Campbell (1957), Instn. Mech. Engrs. Conf. Lubrication and Wear, London, pp. 291–301.

13 Holm, R. (1946), "Electric contacts," Almquist and Wicksells, Uppsala, pp. 214–221.

14 Bowden, F. P. and D. Tabor (1954), "Friction and lubrication of solids," Oxford, Clarendon.

15 Archard, J. F., *Research* **5,** 395–396, 1952.

16 Burwell, J. T., and C. D. Strang, *Proc. Roy. Soc. Lond.* (*A*) **212,** 470–477, 1952.

17 Barwell, F. T. (1957), Instn. Mech. Engrs. Conf. Lubrication and Wear, p. 587.

18 Archard, J. F., *Proc. Roy. Soc. Lond.* (*A*) **243,** 190–205, 1957.

19 Khruschov, M. M. (1957), Instn. Mech. Engrs. Conf. Lubrication and Wear, pp. 655–659.

20 Welch, N. C., *J. Appl. Phys.* **9,** 960–968, 1957.

21 Bisson, E. E., R. L. Johnson and M. A. Swikert (1957), Instn. Mech. Engrs. Conf. Lubrication and Wear, London, pp. 384–391.

22 Trent, E. M., *Proc. Roy. Soc. Lond.* (*A*) **212,** 467–470, 1952.

23 Scott, H. (1957), Instn. Mech. Engrs. Conf. Lubrication and Wear, pp. 606–608.

24 Davison, C. St. C., *Wear* **1,** 2, 155–159, 1957.

Analytical Methods in Applied Mechanics

(See also Revs. 5552, 5557, 5577, 5578, 5579, 5581, 5582, 5585, 5592, 5614, 5657, 5667, 5668, 5677, 5685, 5704, 5710, 5785, 5835, 5879, 5881, 5938, 5953, 6001, 6017, 5045, 5050, 6056)

Book—5541. Hohn, F. E., Elementary matrix algebra, New York, The Macmillan Company, 1958, xi + 305 pp. $10.

By effective grouping of material by chapters around nine well-chosen basic topics, author has achieved a mathematics text of great value to engineers and applied mathematicians. The topics are (1) elementary matrix algebra, (2) determinants, (3) matrix inversion, (4) rank and equivalence, (5) linear equations and linear independence, (6) vector spaces and linear transformations, (7) unitary and orthogonal transformations, (8) characteristic equation of a matrix, and (9) bilinear, quadratic, and Hermitian forms.

This sequence makes for great flexibility. Read or studied in its entirety book proceeds, with proper but not overdone concern for rigor, in gradual stages from simple beginnings through an extremely complete coverage of elementary matrix theory.

For one already somewhat familiar with matrix theory, the self-contained character of each chapter enables the reader to readily obtain a comprehensive and effective treatment of a given topic. For a novice, it will make a fine beginning. The number of examples and the fullness of detail with which they are presented will be appreciated by both of these groups. A rich variety of problems is present. F. Gray, USA

5542. Rutishauser, H., Deflation of bound matrices (in German), *ZAMP* **10,** 3, 314–319 (Brief reports), May 1959.

A bound matrix is a square matrix $A = (a_{ik})$ such that $a_{ik} = 0$ for $|i - k| > m$, where m is a fixed integer. Given an eigenvector of a symmetric bound matrix A, author shows how to construct a matrix H such that $'A = H^T AH = ('a_{ik})$ is symmetric, bound and has $'a_{in} = 0$, $i \neq n$. J. L. Ericksen, USA

5543. Spencer, A. J. M., and Rivlin, R. S., The theory of matrix polynomials, and its application to the mechanics of isotropic continua (in English), *Arch. Rational Mech. Anal.* **2**, 4, 309–336, Jan. 1959.

The present paper is built up on results of Rivlin and Ericksen and Rivlin [*J. Rational Mech. Anal.* **4**, pp. 323 and 681, 1955; AMR **8**(1955), Rev. 3656]. It is shown that any symmetric isotropic matrix polynomial in R symmetrical 3×3 matrices can be expressed as a symmetric isotropic matrix polynomial, in which each of the matrix products is formed from at most 6 matrices and has one of a certain number of forms which are explicitly given. The coefficients are scalar invariants, under the full or proper orthogonal group of transformations, of the R matrices, which may be expressed as polynomials in traces of matrix products formed from these matrices. It is explicitly given a finite integrity basis consisting of traces of certain products of at most 7 (not necessarily different) of the R matrices.

The results are essentially derived by means of the Hamilton-Cayley theorem and its corollaries. With the help of these for any (not necessarily symmetrical) matrix polynomial in 5 and fewer 3×3 (not necessarily symmetrical) matrices all the matrix products that can occur are given. Far-reaching restrictions for the occuring matrix products are given for matrix polynomials of R matrices. Similar results are given for the integrity bases for R symmetrical 3×3 matrices, which are explicitly given for 5 and fewer matrices.

The application of the Peano theorem leads to the mentioned result for symmetric isotropic matrix polynomials in R symmetrical 3×3 matrices. Edda U. Reeh, Germany

5544. Kononenko, V. O., On parametric resonance of a fractional order (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 62–65, Aug. 1958.

Paper deals with nearly periodic solutions of the differential equation

$$d^2x/dt^2 + (b_0 + b_1 \cos \omega t + c \cos \nu t)x = 0$$

with c a small parameter, equation being encountered in problems of motion of charged particles in accelerators and of mechanisms of instruments on oscillating supports. Equation can be easily transformed so that it yields the canonical form of Mathieu's equation, if the parameter c vanishes. Denoting by $\pm i\alpha$ the characteristic indices of this last equation, it is shown that if $\Omega \equiv r \pm i\alpha\nu/\omega$ (where r is an integer or zero) approaches α, the motion becomes unstable. As the instability of motion is connected with fractional values of the index α, this phenomenon is called parametric resonance of a fractional order. Viscous damping has a stabilizing effect on this type of resonance, and a phase angle in the expression of the disturbing force displaces the domains of instability considerably. A. A. Kuhelj, Yugoslavia

5545. Case, K. M., and Dyson, F. J., Stability of an idealized atmosphere, Part 1, Discussion of results; Part 2, Zeros of the confluent hypergeometric function, *Physics of Fluids* **3**, 2, 149–157, Mar./Apr. 1960.

It is shown that an inviscid incompressible fluid moving horizontally, two-dimensionally, and with velocity proportional to height and density decreasing linearly or exponentially is not unstable for small perturbations. Paper is concerned with mathematical techniques for finding eigenvalues for perturbations of given wavelength. Model is of no physical interest.

R. S. Scorer, England

5546. Truesdell, C., Invariant and complete stress functions for general continua (in English), *Arch. Rational Mech. Anal.* **4**, 1, 1–29, Nov. 1959.

Author neatly summarizes and supplements what is known concerning the possibility of expressing general solutions of the equations $T^{km}{}_{,m} = 0$, $T^{km} = T^{mk}$ in terms of sets of arbitrary (stress) functions. He assumes the underlying space is affinely connected and n-dimensional, which includes curved membranes among other things. Discussions of completeness are included. In the main development he concentrates on results valid for all types of materials. However, he includes a special bibliography covering specializations appropriate for linear elasticity and related theories. J. L. Ericksen, USA

5547. Kreiss, H.-O., Difference approximation of high accuracy of initial value problems of partial differential equations (in German), *Numerische Mathematik* **1**, 4, 187–202, Sept. 1959.

An approximate method has been established to reduce a partial differential equation to a difference equation in such a way that local error in the solution becomes of higher order. It has been proved that the solution obtained by the difference equation is stable and converges rapidly to the solution given by the corresponding partial differential equation. Especially, the method is applicable to the partial differential equation appearing in fluid mechanics which belongs to the class of Cauchy's problem.

As an illustration of the method, a solution of a partial differential equation whose coefficients are a matrix of the Hermite type has been worked out in detail.

Reviewer feels this numerical method can be applied to a class of problems in elasticity and boundary-layer theory. The elegance in the proof of necessity and sufficiency of conditions appearing in character of corresponding problems associated with partial differential equations encountered by this method contributes to the high quality of this paper. M. M. Stanisic, USA

5548. Carrier, G. F., Useful approximations in Wiener-Hopf problems, *J. Appl. Phys.* **30**, 11, 1769–1774, Nov. 1959.

The Wiener-Hopf technique [see, for example, B. Noble, "Methods based on the Wiener-Hopf technique for the solution of partial differential equations," Pergamon Press, London, etc., 1958] is well-known, and it has enabled the solution to be found of important boundary-value problems of partial differential equations arising in a wide variety of branches of mathematical physics. However, it is found only too frequently that the technique is limited in its practical application due to mathematical difficulties associated with the kernel involved in the integral equation formulation of the problem which is equivalent to the Wiener-Hopf problem. These difficulties are that the Fourier transform of the kernel must be factored and this may not be achieved simply.

The present paper is concerned with the mathematical artifice of substituting for the actual kernel another kernel whose properties allow the procedure just described to be simple but, at the same time, without consequent loss of representation of essential features in the physical problem being treated. Approximations in Wiener-Hopf problems have been discussed previously by W. T. Koiter [see *Proc. Kgl. Ned. Akad. Wetenschap.* (*B*) **57**, 558–579, 1954]. However, here application to a wider variety of illustrative problems (e.g. in transient heat and viscous flows and radiation of sound) is considered and the procedures involved are rather different. The viewpoint is also specifically taken that an approximate solution of a problem may be just as useful as (or even more useful than) the exact solution provided that the approximate solution mirrors the essential physical features of the problem set. By direct comparison of exact and approximate solutions of various problems, it is found that the kernel substitution approximation is effective when the substitute and actual kernels have the same singularities, area and first moment. If higher moments are also made the same then the accuracy is further improved.

This paper is particularly valuable in emphasizing the usefulness of approximate procedures in Wiener-Hopf problems, particularly from a physical viewpoint.

H. G. Hopkins, England

5549. Rips, Ya. A., Initial production reliability of devices, *Automation and Remote Control* **20,** 6, 788–797, Feb. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 6, 813–822, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Method is suggested for determination of initial production reliability, the magnitude of which is determined by design peculiarities of the device and by production factors. Analytical expressions for computational purposes are deduced, and relationship is shown between initial production reliability and rated safety factors. Cases involving combinations of normal, truncated normal, and uniform probability distributions for characteristics of elements of devices are covered. The effects of additional inspection and finishing are considered, and a method for taking these into account is provided, this method approximating the distribution law by a series of normal distribution laws and their linear combinations. Thus the effects on a device's initial production reliability of the size of established tolerances, quality of materials used, technological and production factors can be estimated.

A. W. Marshall, USA

Book—5550. Ipsen, D. C., Units, dimensions, and dimensionless numbers, New York, McGraw Hill Book Co., 1960, xii + 236 pp. $6.50.

This is an elementary textbook on dimensional analysis with an unusual approach to the subject. The emphasis is on the logical foundations of the subject rather than problem solving. In fact, the conventional problem of the period of a pendulum is not included. The scope is indicated by the chapters. (1) The description of physical ideas; (2) The physical nature of units; (3) The mathematical nature of units; (4) Problems of conversion; (5) The units and dimensions of mechanics; (6) The units and dimensions of thermodynamics and heat transfer; (7) The units and dimensions of electricity; (8) The nature of physical relations; (9) Similitude; (10) Dimensionless relations; (11) The technique of dimensional analysis; (12) Dimensional numbers and their interpretation; (13) The comparison of geometrically dissimilar systems.

Though equations are numerous, the mathematics is quite elementary. No use is made of either determinants or matrices and the π theorem is stated rather loosely without proof. Chapters 7 and 9 do require knowing what a partial differential equation is, but aside from this it might well be possible for bright high school students to follow the text. However, they might not have sufficient background for the problems.

While the book has many good points, the reviewer feels it has defects, some of which could be easily remedied.

Not a single reference is cited, though the author has made an attempt to explain conflicting points of view. A bibliography of a dozen books and papers with a brief comment on each would be a useful addition.

Some tables of dimensions and conversion factors for units should be given. This would save space in stating some of the problems and be more convenient for the reader in the long run.

Some discussion of the use of log-log plots should be included.

The book is well printed in rather large type, but there are no figures and the index is small. The price, therefore, seems somewhat high.

W. Squire, USA

Computing Methods and Computers

(See also Revs. 5547, 5549, 5568, 5579, 5587, 5768, 5789, 5827, 5836, 5840, 5843, 5853, 5903, 5908)

5551. Cot, D., The elements of interpolation (in French), Publ. Scient. Tech. Min. Air, France no. 123, 140 pp., 1959.

Textbook on interpolation and use of finite differences for numerical integration and differentiation. Classical formulas (Newton, Lagrange, Everett, etc.) are derived by elementary methods and their use illustrated. Part 1 deals with functions of one variable and Part 2 with functions of several variables.

M. V. Wilkes, England

5552. Goodey, W. J., Solution of modified linear simultaneous equations—an investigation associated with the analysis of redundant structures, *Aircr. Engng.* **31,** 370, 358-359, 364, Dec. 1959.

At the end of the analysis of a highly redundant structure, the designer sometimes finds it advisable to alter the relative stiffnesses (using this term in its general meaning) of some members of this structure. When his analysis is based on classical methods (the force method or the deformation method) he has solved a set of linear simultaneous equations $Ax + B = 0$. The alteration of some stiffnesses involves the alteration of part of the elements of the matrix A. In order to avoid the necessity to solve again completely the equations with the modified matrix A, author describes a method by which part of the work done in solving the original equation can be utilized.

It depends on the case if this method can really reduce computation work. In some cases the method may be very useful.

A. Werfel, Israel

5553. Whitaker, S., and Pigford, R. L., An approach to numerical differentiation of experimental data, *Indust. Engng. Chem.* **52,** 2, 185–187, Feb. 1960.

Procedure is described for calculation of first and second derivatives from experimental data. Least-squares approximation is made by applying Gram polynomials to five equally spaced points. Use of parabolic fit leads to simple formula for computing derivative at central point. Methods for estimating standard deviation and error of derivative based on least-squares analysis are discussed. Numerical examples of application are given. In Table 1 value of Gram polynomial P_1 for $X = 1$ should be $-1/2$. Reviewer believes method has merit for rapid calculation of derivative when equally spaced data points are available.

R. Guernsey, USA

5554. Dusinberre, G. M., Triangular grids for heat flow studies, *J. Amer. Soc. Naval Engrs.* **72,** 1, 61–65, Feb. 1960.

Paper presents situations in which the use of an irregular triangular grid simplifies the numerical solution of the heat-conduction equation in two-dimensional regions. Author shows that such grids are equivalent to square grids. Reviewer believes that the proof is not convincing and does not reflect recent developments in numerical analysis.

E. H. Wissler, USA

5555. Guest, J., On the choice of suitable functions for solving nonlinear equations by iterative procedures, Aero. Res. Lab., Melbourne, Austral., Note SM 262, 7 pp., Nov. 1959.

Author gives criteria for convergence of iterative methods to determine a root of $f(x, y) = 0$, $g(x, y) = 0$. The extent by which the criteria are over-fulfilled gives an estimate of the speed of convergence.

J. M. Blatt, Australia

5556. Naslin, P., Numerical calculation of the transient regimes of linear and nonlinear systems, methods of numerical simulations, Parts 1 and 2 (in French), *Automatisme* **4,** 7/8, 293–300, July/Aug. 1959; **4,** 9, 340–343, Sept. 1959.

Method consists of a decomposition of bloc diagrams into simple elements that are pure integrations, multiplications, pure delays in direct or feedback loops. Step-by-step computation is performed, at sampling intervals, starting from initial conditions, by standard interpolation technique.

Main interest of this method is the possibility of solving nonlinear equations as easily as linear ones. Response of a diode rectifier associated with capacitors and resistors, and Van der Pol equation are given as instances.

J. M. Loeb, France

5557. Gawronski, R., The application of the analog computer to solutions of some non-linear integral and integrodifferential equations, *Proc. Vibration Problems (Polska Akad. Nauk, Inst. Postawowych Probl. Techn.)* no. 2, 37–42, 1959.

An analog computer system is proposed for the solution, by successive approximation, of certain linear and nonlinear integral equations of the second kind with arbitrary kernel; and, by extension, of some associated, and other, integrodifferential equations. The system contains generators for functions of one and two variables, multiplier, integrator, summing amplifier, and magnetic drum (or tape) storage unit. Unique features appear to be that (1) the voltage generator produces a saw-tooth voltage from which variations of two independent variables may be obtained as a "quick" continuous variation and a "slow," supposedly discontinuous, variation so that integration with respect to the first variable may be performed at constant, and successive, values of the second, and (2) the storage unit, of two identical parts, records "slowly" and reproduces "quickly" successive approximations to the unknown function.

Reviewer considers that the variables t and x should be the "quick" and "slow" variables respectively (conversely to author's statement on p. 38), that provision of special C.R.O. covers with variable transparency may prove very restrictive in practice, and that this account contains insufficient technical detail for a complete assessment to be made of the proposed system.

S. Kirkby, England

5558. Zaid, M., and Ryder, F. L., Electrical analog computer for limit design of structures, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 1 (*J. Engng. Mech. Div.*), 1-17, Jan. 1960.

Authors present design of analog machine particularly suitable for solving limit design problems. Available and relatively inexpensive components are used, with advantages over conventional electrical analog computers which become large as variables increase in number.

Analog computer described is applied to solving a linear programming problem, minimizing a linear function subject to many linear inequalities. Specifically, the paper illustrates computer use in limit design of a one-story, one-bay bent with vertical and horizontal loading. Usual assumptions are made: elastic, ideally plastic members; deformations due only to bending; and weight of members proportional to their length and fully plastic moment. Solution is given for structure of minimum weight that collapses under prescribed loading.

Major portion of paper is devoted to electrical analog and components required. Computer must be fed linear weight equation and numerous inequalities obtained by equations of virtual work. Minimum weight solution is found by inspecting group of hyperplanes until corner is found not violating inequalities. Proposed equipment makes examination of moment space automatic, and convergence to permissible solution is claimed to be rapid.

L. M. Laushey, USA

Analogies

(See also Revs. 5557, 5558, 5612, 5687, 6008)

5559. Palmer, P. J., Copson, Anne R., and Redshaw, S. C., Investigations into the use of an electrical resistance analogue for the solution of certain oscillatory-flow problems, Aero. Res. Counc. Lond. Rep. Mem. 3121, 23 pp., 1959.

An electrical resistance analog was used to give solutions for a thin two-dimensional airfoil oscillating in an incompressible flow. The analog employed graded resistances for increased accuracy.

Experimental results are given for flat plates, with and without flaps, oscillating harmonically with small amplitudes in a steady air stream. These experimental results are in close agreement with theory.

E. K. Parks, USA

5560. Skinner, G. T., Analog network to convert surface temperature to heat flux, *ARS J.* **30,** 6, 569–570 (Tech. Notes), June 1960.

A simple analog network has been devised, for use with thin-film resistance thermometers, which carries out the mathematical operation of transforming surface temperature into heat flux. The method is applicable to shock tube and shock tunnel work. A calibration unit completes the system which eliminates the necessity for complicated computational procedures.

From author's summary

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 5574, 5578, 5581, 5582, 5583, 5586, 5590, 5591, 5612, 5685, 5705, 5883, 6055, 6105)

5561. Wolford, J. C., An analytical method for locating the Burmester points for five infinitesimally separated positions of the coupler plane of a four-bar mechanism, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 182–186, Mar. 1960.

One general procedure for designing planar six-bar coupler-drive mechanisms giving a dwell uses the so-called Burmester points. A Burmester point is a point of the coupler where the coupler-curve has fifth-order contact with its circle of curvature. This paper makes available a third method for locating the Burmester points for the motion of the coupler plane of the four-bar linkage. Like Allievi's method, it is an analytical scheme, although there are points of difference. The older and completely graphical method, that of Müller, while adequate for many tasks, does not carry the precision of analytical methods, but is of distinct value for running a rapid check or guidance. Wolford's method, straightforward and relatively easy to apply, is most welcome since it furnishes another independent route to the objective.

R. S. Hartenberg, USA

5562. Paul, B., A unified criterion for the degree of constraint of plane kinematic chains, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 196–200, Mar. 1960.

Criteria of constraint are ordinarily discussed for so-called general cases that fail to include special configurations lying outside the regime of the formulas of the general cases. This paper presents a view that facilitates the analysis for the degrees of freedom of plane kinematic chains consisting of only lower pairs. The analysis, topological in character, is based on the recognition of independent closed loops formed by the linkage; the links of any given loop are viewed as directed line segments forming a closed vector polygon. From these independent loops the governing equations for determining the unknown velocities and accelerations may also be formulated.

Three special cases are considered. The first is concerned with chains having an overconstrained part and a movable part: here the constrained part is found and the degree of freedom of the movable part determined. The second case deals with the presence of permanent critical forms in the chain, configurations giving degrees of freedom at first unsuspected from formula criteria alone. The last case treats chains consisting entirely of sliding pairs, and is not given a detailed discussion because of the "poor frictional characteristics . . . which . . . prevent wide usage of such construction." This may be an oversight in the light of further developments in ball-bearing splines.

R. S. Hartenberg, USA

5563. Magnus, K., The heavy symmetrical gyroscope on gimbals (in German), *Ing.-Arch.* **28,** 184–198, Mar. 1959.

Rotor possessing kinematic symmetry is mounted on gimbals, dissipative forces, e.g. friction in the bearings, being absent.

Lagrangian of entire system (gimbals and rotor) which can be written in terms of suitably chosen Euler angles shows that one angle is ignorable. Thus two first integrals of motion are immediately available corresponding to the ignorable coordinate and conservation of energy. Author shows that a second angle is ignorable if outer gimbal axis is parallel to gravitational field and hence third first integral is found. Detailed analysis of precession and stability founded on these three integrals is presented.

T. P. Mitchell, USA

5564. Mettler, E., Stability problems for freely vibrating mechanical systems (in German), *Ing.-Arch.* **28**, 213–228, Mar. 1959.

Considering a system with n degrees of freedom, the Lagrangian equations of motion in normal coordinates are, in general, coupled by nonlinear terms which are omitted in linear theory. Author is concerned with the question as to what extent the linear theory is a reasonable approximation for arbitrarily small amplitudes of vibrations.

In particular, the system of differential equations may be such that a rigorous solution exists when some of the coordinates are zero, corresponding to equilibrium positions, while the remaining coordinates are periodic functions of time. The question now is if, and under what circumstances, such a solution is stable, i.e. the first mentioned coordinates remain arbitrarily small, when disturbed.

Author derives a system of linearized differential equations with variable coefficients, the solution of which will contain the answer to the question of stability.

Three illustrative examples are treated in some detail yielding nontrivial results, and author points out cases of practical interest in which the phenomenon of instability may occur and introduce undesirable vibrations.

F. I. Niordson, Denmark

5565. Skalak, R., and Yarymovych, M. I., Subharmonic oscillations of a pendulum, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 159–164, Mar. 1960.

The support of the pendulum moves with a given vertical oscillation. Therefore the motion of the pendulum is governed by the nonlinear Mathieu equation with damping of the form

$$\theta'' - 2k\,\theta' + (a - n^2 q \cos nz)\sin\theta = 0$$

where z is the dimensionless time. Author replaces the term $\sin\theta$ by the first terms of the series and studies the resulting equations of approximation, using the harmonical linearization. He is particularly interested in the subharmonics of order $\frac{1}{2}$ to $\frac{1}{5}$, the stability of which is discussed by the method of Andronov and Witt. The results are interpreted by diagrams and compared with experiments.

W. Hahn, India

5566. Sethna, P. R., Steady-state undamped vibrations of a class of nonlinear discrete systems, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 187–195, Mar. 1960.

Assuming that the potential energy of the system is of a special type (sum of a quadratic and a biquadratic form of the general coordinates) author obtains the equation of motion in the Lagrangian form. He introduces the principal coordinates corresponding to the linear part, the method being restricted to vibrations in the neighborhood of free linear vibrations of the system, and uses perturbation scheme to obtain the solution approximately. Generally, the method seems to require rather complicated computations. Author discusses the results of the first (nonlinear) approximation in some simpler cases, concerning problems of two and three degrees of freedom. The interesting results are given by diagrams and checked against those obtained from an analog computer with good correspondence.

W. Hahn, India

5567. Greenspon, J. E., A simplified expression for the period of nonlinear oscillations of curved and flat panels, *J. Aero/Space Sci.* **27**, 2, 138–139 (Readers' Forum), Feb. 1960.

The formula for the period is the same as for a simple pendulum. Author derives the well-known expansion in series of the amplitude.

D. Graffi, Italy

5568. Walton, T. S., and Polachek, H., Calculation of transient motion of submerged cables, *Math. Comput.* **14**, 69, 27–46, Jan. 1960.

Authors describe computational procedure for determining motion of submerged cables, considering effects of cable weight, buoyancy, drag, and virtual inertia of medium. Stability of numerical method is investigated, and some actual results are plotted. Paper is interesting contribution to both oceanography and computation; reviewer feels however that since cable elements are inextensional, choice of section angles rather than sets of two space coordinates as independent variables might have simplified analysis.

C. E. Pearson, USA

5569. Filippov, A. P., Forced vibration of a linear system for passage through resonance with a nonlinearly varying frequency (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 12, 47–52, Dec. 1958.

Paper presents the problem of damped forced vibrations when the perturbing force changes as the polynomial of the third power of time. Making use of the transformation and assuming that the ratio $\mu/k = 1/\lambda$ is small, where μ is damping factor, $k^2 = \omega^2 - \mu^2/4$, $\omega^2 = \text{cm}^{-1}$, the case of the maximum amplitude of linear system passing through the resonance is treated in detail. In this case the solution is obtained by means of Lommel's functions using the asymptotic development of Fresnel's integrals. The resonant curves in the case when the instantaneous frequency changes as the fourth power of time are plotted. Finally, author treats the case when the amplitude of perturbing force is proportional to the second power of the frequency, i.e. when the centrifugal force of unbalanced mass is operating. Author concludes that in this case the amplitude, in the vicinity of the resonance, is very little different from the case when the perturbing force is constant.

D. Raskovic, Yugoslavia

5570. Ishlinskii, A. Yu., Malashenko, S. V., and Temchenko, M. E., On bifurcation of stable positions of dynamic equilibrium of a mechanical system (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 53–61, Aug. 1958.

Stable positions of relative equilibrium of rotating mechanical systems usually become unstable when the critical rotating velocity is reached and therefore the system passes always automatically into the other position of equilibrium if the angle velocity is further increased. An elongated body, tied to a vertical rotating axis by an inextensible string, possesses two velocities of bifurcation; but it is shown theoretically that the inferior vertical position of the body is stable for all velocities of rotation, and the same applies to the other two positions of relative equilibrium if the rotating velocities are greater than the corresponding velocities of bifurcation. Experiments have confirmed theoretical predictions, and strong disturbing forces in an appropriate direction are necessary in order to bring the system from one position to the other when the velocity of bifurcation is surpassed.

A. A. Kuhelj, Yugoslavia

Instrumentation and Automatic Control

(See also Revs. 5549, 5949, 5999, 6075, 6076, 6077, 6080, 6081)

5571. Chekhonadskii, N. A., A general approach to the analysis of static and dynamic errors, *Measurement Techniques* no. 3, 156–160, May 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no.

3, 2–4, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The laws operating when measurements are carried out both statically and dynamically may be expressed by general relationships.

As a result of an application of the expressions obtained for the dynamic error analysis, it can be established that the dynamic error determined experimentally is, by its meaning, a systematic error of an apparatus operating dynamically. In addition to this error, a random error also arises when measurements are made dynamically.

Results of measurements carried out by the apparatus both statically and dynamically may be expressed by similar expressions containing the basic characteristics of the apparatus for these operating conditions; this should make it easier to resolve static and dynamic problems involved in the construction of apparatus.

From author's summary

5572. Dunin-Barkovskii, I. V., and Karpasheva, A. N., On the quality evaluation of methods for checking measurement instruments, *Measurement Techniques* no. 6, 616–624, Mar. 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 6, 6–10, Nov./Dec. 1958 by Instrument Society of America, Pittsburgh 22, Pa.)

An application of statistical analysis and statistical control to decisions on the accuracy of measuring instruments. By means of curves of operating characteristics of quality testing and selection rules, different rules can be compared for over-all quality control. According to the paper, there is a tendency in Soviet practice to commit errors of the second kind, i.e. accepting a bad instrument. The effects of test rules, sample sizes, allowed error limits and inherent error are compared. This is a fairly straightforward application of operating characteristic analysis, but the paper must be recognized as a good example in application. No attention, however, was paid to differentiating "reading" errors from errors in the measurements themselves.

The translation persists in referring to *operative* characteristics, which is good Russian but bad English. The difficulties of translation are readily understood but technical terms should be used in standard form wherever possible. Sentence structure could also be improved; the pressure of publication dates probably accounts for these shortcomings.

E. Koenigsberg, USA

5573. Kliukin, I. I., Error of vibrometer reading due to its reaction on vibrating surface, *Measurement Techniques* no. 6, 648–655, Mar. 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 6, 30–35, Nov./Dec. 1958 by Instrument Society of America, Pittsburgh 22, Pa.)

Analytical and experimental investigation of the effect of vibration pickup mass on the amplitude measured in flexural vibrations of a thin duralumin plate. The plate, 1.5 × 2.2 meters, and 1.5 mm thick, was driven at frequencies from 100 to 2000 cps. To simulate pickups of different masses having equal frequency response and sensitivity, a single piezoelectric unit weighing 25 grams was used, the measurements with this alone being used as reference values. Additional masses were then added to bring the total mass to 100 and 1000 grams. Experimental results are plotted as the differences, in decibels, between the attenuations observed with the larger masses and with the 25 gram mass. Observed attenuations increase with frequency and pickup mass, being about 22 decibels at 2000 cps with the 1000 gram mass. Agreement between experimental values and those predicted by the author's theory is good, except for the 1000 gram mass at the lower frequencies, where measured attenuations are smaller than theoretical. Use of the results for estimation of the useful frequency ranges of pickups, when used on other materials and shapes, is discussed.

A study is made of the attenuation to be expected when a vibration pickup and wide-band amplifier are used to measure the mean vibration level over a frequency range in which there is a spectrum of vibration levels which is uniform, or which increases or decreases by a uniform number of decibels per octave.

W. F. Stokey, USA

5574. Fleer, A. G., General solution of Airy's problem in chronometry, *Measurement Techniques* no. 5, 537–539, Feb. 1960. (Translation of *Izmeritel'naia Tekhnika USSR* no. 5, 35–37, Sept./Oct. 1958 by Instrument Society of America, Pittsburgh 22, Pa.)

As a problem of forced vibrations author solves Airy's problem in chronometry when pulse is a continuous function of time. Friction is also taken into account. Following theorem was proved: "In order that oscillations with an amplitude incremented by the pulse should be in phase with the oscillations which existed in the system before the external pulse, which is distributed in time, was applied to it, it is necessary and sufficient that initial conditions be $t = 0$, and $\varphi = A$

$$\int_{t_0}^{t_1} f(t)\, e^{\delta t} \cos \omega t \, dt = 0."$$

K. Piszczek, Poland

5575. Weltbrecht, W., and Sinn, G., Logical transistorized functional units for industrial open loop control systems (in German), *Regelungstechnik* **8,** 3, 84–89, Mar. 1960.

5576. Buhring, K., Electrical open loop control systems and components for industrial actuators (in German), *Regelungstechnik* **8,** 3, 90–97, Mar. 1960.

5577. Dudnikov, E. E., Determination of transfer function coefficients of a linear system from the initial portion of an experimentally obtained amplitude-phase characteristic, *Automation and Remote Control* **20,** 5, 552–558, Feb. 1960. (Translation of *Avtomatika i Telemekanika* **20,** 5, 576–582, May 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Author describes method yielding approximate values of coefficients for a function whose analytical structure is not prescribed in advance. A general formulation of a linear lumped parameter system transfer function is transformed into a simplified format, portions of which may be plotted separately using experimental data to give estimates of the transfer coefficients. Estimates are determined by limiting conditions as frequency vanishes. A numerical example is presented. Author states another version of method is available using limits as the frequency increases infinitely.

Reviewer believes method is better suited to digital computer techniques than to manual plotting procedures which could be exceedingly tedious.

R. B. Grant, USA

5578. Reissig, R., Stable behavior in case of periodic excitation (in German), *Monatsberichte Deutschen Akad. Wissenschaften, Berlin* **1,** 4, 205–211, 1959.

LaSalle [*Ann. Math.* **65,** 571–581, 1957] obtained conditions ensuring that a motion due to periodic forces would be stable under a sufficiently small pulse disturbance. Author here establishes that the same conditions ensure stability under a sufficiently small continuing perturbation.

C. M. Ablow, USA

5579. Phillips, J. A., The determination of the natural modes of a physical system, Aero. Res. Lab. Melbourne, Austral. Rep. I. 21, 79 pp., June 1959.

The poles of a transfer function $G(p)$ may be eliminated by introducing a tandem system having zeros corresponding to the poles of $G(p)$. Generation of systems with movable zeros and their application is the purpose of the report. Two realizable methods are discussed in detail: (a) feedback circuits using RC networks, (b) analog computer or differential analyzer circuits. As both systems

produce a pair of complex conjugate poles, the zeros are obtained by inversion. Because inversion introduces new poles, these have to be removed from the movable zeros as far as there is no disturbing influence. The zeros are given in polar co-ordinates (a) or rectangular ones (b).

Settling of a RC network with an amplifier having positive gain in the feedback path and a pulse as forcing function is described in detail and accuracy estimated. Results of measurement of transfer functions with one real pole, a pair of real poles and a pair of complex conjugate poles are given in tables and the transient responses sketched for the zeros marking the poles and the zeros being near the poles.

Author points to the possibilities of improving the method used, but maintenance of stability of the inversion loop will become more difficult. Application to nonlinear systems seems possible.

P. J. Profos, Switzerland

5580. McCausland, I., Adaptation in feedback control systems, *J. Franklin Inst.* **268,** 3, 143–147, Sept. 1959.

5581. Kupriyanova, L. I., The stability of a nonlinear control system with a neutral object, *Automation and Remote Control* **20,** 2, 122–129, Jan. 1960. (Translation of *Avtomatika i Telemekanika USSR* **20,** 2, 127–134, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Lyapunov's direct method is used to solve for the stability of the transient motion in a nonlinear control system that has a neutral object. It is shown that it is possible to estimate how variability in the coefficients affects the stability limits. It is also shown that it is best to consider nonlinear functions of a certain definite class when one considers the equation for the effector in such control systems.

From author's summary by L. A. Gould, USA

5582. Krutova, I. N., Study of periodic motions arising in a servomechanism oscillatory circuit at constant excitation, *Automation and Remote Control* **20,** 5, 541–551, Feb. 1960. (Translation of *Avtomatika i Telemekanika* **20,** 5, 564–575, May 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A circuit with dual parallel control channels is discussed. Taken from a mechanical pilot servo, the circuit consists of two amplifying tube stages and relays connected in the anode circuits of the last stage, which is separated into two channels. The feedback circuit has a link providing a delay in signal variation when the feedback circuit is closed or open. The mathematical model presented consists of three first-order differential equations. The nonlinear model is studied using phase plane and point transformation theory. Numerous phase plane maps are provided to clarify the analysis.

Detailed results are given pertinent to the stability and purity of oscillations arising with constant excitation. Important oscillatory parameters and static circuit characteristics are determined.

Reviewer believes article represents a good example of nonlinear analysis applied to a specific problem.

R. B. Grant, USA

5583. Nowacki, P. J., The treatment of nonlinear problems in control engineering (in German), *Regelungstechnik.* **8,** 2, 47–50, 1960.

Author wants to use the Laplace transform for solving nonlinear control problems. He considers a system described by the differential equation $\Sigma a_\nu x^{(\nu)} + f(x, \dot{x}) = z(t)$, where $f(x, \dot{x})$ is a nonlinear function and $z(t)$ is a given function of time. A well-known iteration process is suggested. The first solution x_1 is obtained by neglecting $f(x, \dot{x})$; the second solution is obtained by employing x_1 for computing an approximate value of $f(x,\dot{x})$, and so on. For an example $\ddot{x} + (1 + V)\dot{x} + \tau x = 0$ with $V = V_0 + ax^2$ and $\tau = \tau_0 + bx^2$, the second solution x_2 is compared to a solution obtained by a finite difference method. In the following section author discusses a control problem described by $\ddot{x} + f(x)\dot{x} + x = 1$. By setting $f(x) = f_n = \text{const}$ for $x_n < x < x_{n+1}$ he obtains a linear differential equation for each interval, which he again solves with the Laplace transformation. An example is given.

Irmgard Flugge-Lotz, USA

5584. Brack, G., Contribution to the introduction of nonlinearities in control system (in German), *Automatisierung: Z. Messen, Steuern, Regeln* **2,** 4, 166–172, Aug. 1959.

First the author discusses, for certain disturbances, the improvements in the behavior of a control-system defined by

$$\ddot{x} + 2\xi < x > \omega_0 \dot{x} + \omega_0^2 x = 0$$

by introducing nonlinear continuous or discontinuous damping-factors $\xi < x >$ and shows by means of experimental transient curves and by diagrams, especially in phase-plane, the different effects caused by varying the parameters. Then he investigates an example of an optimal operating three-point-control-system. General remarks on the influences of nonlinearities are made.

H. St. Stefaniak, Germany

5585. Sobolev, Yu. S., The absolute stabilities of certain controlled systems, *Automation and Remote Control* **20,** 4, 389–393, Jan. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 4, 401–405, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Author shows that absolute stability regions of some nonlinear systems are same as regions of stability of derived linear systems with parameter; variation of parameter gives bound to absolute stability region. Thus methods of linear analysis may be applied. Method is not limited by number of nonlinearities.

R. D. Milne, England

5586. Shao, D.-C., On the possibility of certain types of oscillations in sampled-data control systems, *Automation and Remote Control* **20,** 1, 77–82, July 1959. (Translation of *Avtomatika i Telemekanika* **20,** 1, 85–89, Jan. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Author considers the possibility of self oscillations in sampled-data control systems. The system considered is of the pulse-modulated type in which the input is sampled periodically. The sampler generates a constant height pulse whose duration is proportional to the magnitude of the input, and whose sign is the same as the sign of the input. Author derives the conditions for symmetric self-oscillations with a period twice the period of the sampler. The stability of the limit cycles is analyzed and the conditions for stable self-oscillations derived.

T. K. Caughey, USA

5587. Krasovskii, A. A., On the synthesis of pulsed correcting devices for servosystems, *Automation and Remote Control* **20,** 6, 706–717, Feb. 1960. (Translation of *Avtomatika i Telemekanika USSR* **20,** 6, 729–739, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Author treats problem of determining the optimum correcting function for a linear sampled-data system when the input consists of stationary random noise and either a slowly varying input or a random input.

Solution is in the form of a finite series of samples representing the impulse response of the system. The system is optimum in the sense that the mean square error is minimized. The method used is straightforward differential calculus to determine the unknown coefficients of the impulse response.

L. A. Gould, USA

5588. Milsum, J. H., Random signals in engineering systems, Nat. Res. Counc. Canada, Div. Mech. Engng. and Nat. Aero. Establishment, Quart. Bull. no. 1, 13–41, Jan./Mar. 1960.

5589. Andreev, N. I., A theory for determining optimum dynamic systems, *Automation and Remote Control* **19,** 12, 1049–1062, June 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **19,** 12, 1077–1090, Dec. 1958 by Instrument Society of America, Pittsburgh 22, Pa.)

This is a very mathematical paper. Perhaps the essential content can best be epitomized in the author's summary (as given in translation). "The paper gives the necessary and sufficient conditions for an extreme in functional

$$I = \Phi\{I_1[k(t)], \ldots, I_{n+1}[k(t)]\}$$

for the case when the necessary and sufficient conditions for the extreme in the functional

$$I_l = \theta_1 I_1 + \ldots + \theta_n I_n + I_{n+1}$$

are known. The results obtained in the paper can be used in selecting optimum dynamic systems.

Particular examples at the end of the paper show that the use of a more complex criterion (P or P^2) leads in certain cases to an increase in the quality of the selected system (i.e., P or P^2)."

Herein, $k(t)$ represents a probability function. Paper primarily is of interest to those concerned with systems subjected to random inputs. T. J. Higgins, USA

5590. Tupitsyn, A. I., An integral estimate for selecting the optimum parameters of an automatic control system with a given overshoot, *Automation and Remote Control* **20,** 4, 394–402, Jan. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 4, 406–414, Apr. 1959 by Instrument Society of America, Pittsburgh, 22, Pa.)

Optimization of autopilot by criterion that integral of square of deviation from new controlled value be a minimum leads to transient response with large overshoot. Author uses an additional optimization condition to limit overshoot to a given value. Formulas for estimating response time are given. Several examples are worked out showing good agreement between estimated and actual response times. R. D. Milne, England

5591. Matytsin, V. D., and Ryapolov, V. A., Use of an integral-square estimate to determine the optimal parameters of an autopilot with rate feedback, *Automation and Remote Control* **20,** 4, 403–408, Jan. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 4, 415–421, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Optimization of an autopilot with rate feedback is studied, criterion used being that integral of square of deviation from required course angle is a minimum.

Analytic relations are deduced connecting the three autopilot transfer numbers in terms of aircraft stability derivatives. These formulas serve as starting points in making a final choice of autopilot parameters by analog computer. An example is worked out. R. D. Milne, England

5592. Matveev, P. S., A method of determining the optimal pulse response function for one class of disturbances, *Automation and Remote Control* **20,** 1, 1–12, July 1959. (Translation of *Avtomatika i Telemekanika* **20,** 1, 3–15, Jan. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

In this excellent paper author presents a method for determining the optimum pulse response function for a servo system in the case where the input consists of given harmonic and exponential functions of time plus a stationary random function. The method makes use of the relationship existing between the Green function and the correlation function for a self-adjoint differential system. Two examples are worked out to illustrate the method. T. K. Caughey, USA

5593. Kazakevich, V. V., On the process of extremum control of systems having inertia in the presence of perturbations, *Soviet Phys.-Doklady* **4,** 3, 578–581, Dec. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N. S.)* **126,** 3, 517–520, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Methods are proposed for improving the response of an extremum (relay type) regulator controlling a load with large inertia or a process subject to large random disturbances. Method of operation is to add to the control signal a modulating oscillation, whose frequency may be constant or be varied periodically.

Experimental apparatus used for achieving this type of control is described and a significant improvement in performance is claimed. No figures from experimental results are quoted. The translation is comprehensible but the technical words and phrases are frequently not those in normal use and sometimes tend to be misleading (e.g. "perturbation" for "disturbance"). R. H. Macmillan, England

Book—5594. Blackburn, J. F., Reethof, G., and Shearer, J. L., edited by, Fluid power control, New York, John Wiley & Sons, Inc., 1960, xx + 710 pp. $17.50.

This book draws together into a single volume a wealth of material which, for the most part, has been previously published in numerous technical journals. It draws heavily (and somewhat one-sidedly) on the work of the Dynamic Analysis and Control Laboratory at the Massachusetts Institute of Technology. The various chapters have been authored by persons who have contributed importantly to the subject material. This multiple authorship is evidenced by differences in treatment and notation. However, taken as a whole, the book is valuable as a comprehensive single reference work for anyone concerned with the design of fluid controls and drives. The book is not intended as an exhaustive treatment of the subject material and theory is developed only to the point of establishing quantitative design criteria.

The book logically can be divided into three sections. The first section (chapters 1–5) provides background material, including a review of some of the fundamentals of fluid mechanics. The second portion of the book (chapters 6–13) deals with the design of fluid controls and drives, while the concluding section (chapters 14–20) is devoted to applications and a review of the fundamentals of system dynamics. S. Z. Dushkes, USA

5595. Solodovnyikov, V. V., Some basic theoretical principles of complex automation (in Hungarian), *Meres Es Automat.* **7,** 8/9, 208–215, 1959.

In constructing up-to-date control systems, complex automation fulfills the requirements in the controlling technical processes entirely eliminating the human sensing and controlling elements.

The basic principles of complex automation have been recently introduced and the development of these principles require a fundamental theoretical investigation. This article deals with the basic principles of complex automation and shows the theoretical fields in which the synthesis of the developments can give the theoretical aspects of complex automation. From author's summary

5596. Eifert, G., Closed-loop controls in the chemical industry (in German), *Automatisierung: Z. Messen, Steuern, Regeln* **3,** 1, 12–15, Jan. 1960.

First, essential suppositions for a sensible and promising automating are treated. The fundamentals of control are briefly explained. Furthermore, the closed-loop controls at a distilling column, a temperature control, and a bypass control are discussed in detail. In simple control schemes the different designs find their representation. In conclusion, author reports on the complete automation in the chemical industry. From author's summary

5597. Kolf, R. C., and Zielinski, P. B., The vortex chamber as an automatic flow-control device, *Proc. Amer. Soc. Civ. Engrs.* **85,** HY 12 (*J. Hydr. Div.*), 1–8, Dec. 1959.

Coefficients of discharge for flow through horizontal orifices are greatly reduced when a vortex is present. Several flow control devices have been designed utilizing this phenomenon. This paper presents a rational explanation of the resulting coefficient variation from dynamic similarity. The results of laboratory experiments are shown, giving a means of predicting orifice flow characteristics from the inlet velocity condition.

From author's summary

5598. Gill, H., Experimental analysis of tandem mill control equations, Instn. Mech. Engrs., Prepr., 1959, 13 pp.

This work is concerned with an experimental analysis of tandem mill control equations as developed by Hessenberg and Jenkins. A 3-stand model scale mill was used to study the effect on steady-state conditions of three different forms of disturbance, namely front tension changes, screw adjustments, and variations in ingoing gage. The object of the experiments was to investigate the conditions for maximum inherent stability of the mill as a whole unit. The effect of changes in stand rigidity and motor speed regulation are discussed in detail and conclusions drawn regarding the settings for optimum performance when the gage is controlled by screw movements in the early stands combined with tension variations in the latter. From author's summary

5599. Dorand, R., The application of the jet flap to helicopter rotor control, *J. Helicop. Assn.* **13,** 6, 323–367, Dec. 1959.

Tables, Charts, Dictionaries, etc.

(See Revs. 5621, 5883)

Elasticity

(See also Revs. 5543, 5546, 5566, 5632, 5634, 5636, 5637, 5641, 5643, 5653, 5654, 5664, 5666, 5667, 5668, 5671, 5685, 5691, 5698, 5700, 5707, 5710, 5721, 5730, 5740, 5797)

5600. Jeffreys, H., Faults in a material that hardens when it yields, *Proc. Roy. Soc. Lond.* (*A*) **252,** 1271, 431–435, Oct. 1959.

A two-dimensional elongated rigid flaw, embedded within an infinite isotropic elastic medium, perturbs an otherwise uniform stress field. What are the perturbed stresses in its neighborhood? Using complex variable methods, author concludes that the dominant stress component acts parallel to the flaw, in contrast to a crack, where the dominant component acts normal to the flaw. Some aspects of mineral formation are discussed in the light of this analysis. M. A. Jaswon, England

5601. Khrustalev, A. F., and Kogan, B. I., A boundary problem for a biharmonic equation met with in the theory of elasticity (in Russian), *Izv. Vyssh. Uchebn. Zavedenii Matematika* **3,** 241–247, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6624.

The biharmonic equation $\Lambda^2\chi(r, z) = 0$ is integrated with the boundary conditions

$$\sigma_r = \frac{\partial}{\partial z}\left(\nu\Lambda\chi - \frac{\partial^2\chi}{\partial r^2}\right) = 0, \qquad r = R, \qquad 0 < z < \infty \qquad [1]$$

$$\tau_{rz} = \frac{\partial}{\partial r}\left[(1-\nu)\Lambda\chi - \frac{\partial^2\chi}{\partial z^2}\right] = 0, \qquad r = R, \qquad -\infty < z < \infty \qquad [2]$$

$$\alpha\sigma_r + \beta u = \gamma, \qquad r = R, \qquad -\infty < z < 0 \qquad [3]$$

Here

$$u = -\frac{1+\nu}{E}\frac{\partial^2\chi}{\partial r\,\partial z}, \qquad \alpha, \beta = \text{const} > 0$$

To commence with, a formal solution is sought for $\chi_0 = e^{mz}\varphi(r)$, where φ is linearly expressed through $J_0(mr)$ and $J_1(mr)$ and then a solution is sought

$$\chi(r, z) = \int_{-j\infty}^{0-;\,+j\infty} \chi_0(r, z, m)\,dm$$

which will satisfy condition [2]. Having done that, conditions [1] and [3] are satisfied. Function χ is presented in a compact form as indicated by the integral of the contour. Calculations are made for σ_r and τ_{rz}. It is worth mentioning that a study of the stressed state of the cylinder with $z \to -\infty$ is in correspondence with the study of the plane problem for a cylinder with boundary conditions $\alpha\sigma_r + \beta u = \gamma$, $\tau_{rz} = 0$ with $r = R$, $|z| < \infty$. σ_r and u are calculated for small values for z with $r = R$. Treated as particular cases, three cases of selection of constants α, β, γ are referred to as corresponding to various problems connected with the deformation of a cylinder. I. S. Arzhanykh

Courtesy Referativnyi Zhurnal, USSR

5602. Golovin, A. Ya., Some problems on the equilibrium of an elastic plane and an elastic semiplane (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 196, 46–72, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6626.

It is shown that the solution of the plane problem in the theory of elasticity for an infinite plane, in which spatial forces $Y = Y(x, y)$ are acting, can be obtained from the solution of the problem on the deflection of an infinite plate, loaded with a normal load $q(x, y) \equiv Y$. Formulas are given for the stresses and transpositions

$$\sigma_x = -\frac{\partial}{\partial y}\left(\frac{1}{1-\nu}\frac{\partial^2 w}{\partial y^2} - \Lambda w\right)$$

$$\sigma_y = -\frac{\partial}{\partial y}\left(\frac{1}{1-\nu}\frac{\partial^2 w}{\partial x^2} + \Lambda w\right)$$

$$\tau_{xy} = \frac{\partial}{\partial x}\left(\frac{1}{1-\nu}\frac{\partial^2 w}{\partial y^2} = -\Lambda w\right)$$

$$u = \frac{1+\nu}{E(1-\nu)}\frac{\partial^2 w}{\partial x\,\partial y}$$

$$\nu = -\frac{1+\nu}{E(1-\nu)}\left[\frac{\partial^2 w}{\partial x^2} + (1-2\nu)\Lambda w\right]$$

where w is the deflecting of the plate (the flexural rigidity being equal to (1)). It is then possible to obtain the corresponding solution for an infinite plane by using the already known results in the theory of plates. The action of a concentrated force and of forces distributed along a straight section is investigated; the latter problem converges with the theory of the potential. Calculation formulas are obtained for the tangential and normal loads when evenly and linearly distributed along the section. A solution is given for the problem of the equilibrium of a semiplane under the action of an arbitrary load, applied to its boundary, which merges with the search for a harmonic function $\theta = \sigma_x + \sigma_y$. By combining the solutions of the problem for a plane and a semiplane the author obtains solutions for new problems. In this way he found the stressed state of a semiplane under the action of a concentrated force applied at a point at some distance from the boundary; he also investigated the action on the semiplane of forces distributed along the cutting, carried out inside the semiplane.

V. K. Prokopov

Courtesy Referativnyi Zhurnal, USSR

5603. Bagrov, I. A., Solution of a plane problem in the theory of elasticity in stepped polynomials (in Russian), *Trudi Novosib. In-ta Inzh. Zh.-d Transp.* no. 14, 189–206, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6628.

Formulas are put forward which determine the coefficients of biharmonic polynomials through the coefficients of step-by-step loading on the longitudinal edges $y = \pm 1$ and the values for the specific forces in a section $x = 0$ of a rectangular plate.

V. K. Prokopov

Courtesy Referativnyi Zhurnal, USSR

5604. Kakhniashvili, N. S., Investigation of plane problems in the theory of elasticity by use of the method of the theory of potentials for regions with many linkages (in Russian), *Trudi Tbilissk. In-ta* **56**, 173–183, 1955; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6629.

The conditions are indicated governing the solvability of plane problems in the theory of elasticity for regions with many linkages, with an assigned vector of transposition on the boundary (or a vector of stress) in the form of generalized static potentials of a double (or simple) layer of the first order.

V. K. Prokopov

Courtesy Referativnyi Zhurnal, USSR

5605. Prussov, I. O., An elastic semi-plane with a reinforced circular opening (in Ukrainian), *Nauk Zap. L'vivsk. In-ta* **44**, 17–21, 1957; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9056.

The stress distribution in an isotropic, imponderable semi-plane, weakened by a circular cut-out, the edge whereof is reinforced by a ring of constant cross section, is analyzed by the method of linear conjugation. Numerical examples for a particular case are presented. A particular case of this problem was investigated by I. G. Armanovich [*Dokladi Akad. Nauk SSSR (N.S.)* **104**, 3, 372–375, 1955], who used D. I. Sherman's method for obtaining a solution.

V. I. Tul'chu

Courtesy Referativnyi Zhurnal, USSR

5606. Wittrick, W. H., The stresses around reinforced elliptical holes in plane sheet, Aero. Res. Lab., Melbourne, Austral., Note SM 267, 45 pp., May 1959.

N. I. Muskhelishvili's complex variable approach is applied to a group of plane stress problems which are primarily directed toward the determination of the stress distribution around window openings in pressurized fuselages. Applied tractions at infinity include arbitrary constant system as well as bending; the hole is stress-free except for the effects of the reinforcement. The approach is general and can be applied to other hole shapes for which mappings to the unit circle are available.

Treatment for the ellipse is extensive and includes closed-form solutions for special cases together with tables and graphs for varied reinforcement, axis ratios, and loading systems.

R. A. Eubanks, USA

5607. Uemura, M., Deformation and thermal stress of rectangular beams or flat strips heated at one surface, Aero. Res. Inst., Tokyo University, Rep. 352, 49 pp., Mar. 1960.

Some elementary problems in thermal stress analysis and thermal buckling of long rectangular strips are analyzed by employing thermodynamics and finite deformation theory. Results are presented analytically and graphically.

H. Becker, USA

5608. Knops, R. J., A method for solving linear thermoelastic problems, *J. Mech. Phys. Solids* **7**, 3, 182–192, June 1959.

Two component states of stress and displacement are considered satisfying the same boundary conditions and associated with the same shear modulus but different Poisson's ratios. It is observed that the Hooke stress-strain relations governing the resultant state, obtained by subtracting the corresponding relations for the component states, are identical in form to the thermoelastic equations of Duhamel-Neumann (the resultant boundary conditions becoming homogeneous). This makes it possible to utilize the known isothermal solutions for the derivation of solutions of thermoelastic problems. Of course, there are some difficulties in producing realistic temperature fields by this inverse procedure. However, the method, if applied to problems of the half-space and of the infinite thick plate, supplies much simpler solutions than other known methods.

J. Nowinski, USA

5609. Forray, M., Formulas for the determination of thermal stresses in rings, *J. Aero/Space Sci.* **27**, 3, 238–240 (Readers' Forum), Mar. 1960.

The ring is plane and the two-dimensional temperature distribution is expressed in terms of $E\alpha T = r^k \cos n\theta$, $k = 0, 1, 2\ldots$, $n = 0, 1, 2\ldots$.

Expressions for the stresses are given in polar coordinates. In these expressions 8 unknown coefficients still occur which are to be determined from the condition that at inner and outer radius the ring is stress free. Some special cases are further considered.

J. P. Benthem, Holland

5610. Eason, G., and Sneddon, I. N., The dynamic stresses produced in elastic bodies by uneven heating, *Proc. Roy. Soc. Edinburgh (A)* **65**, 10, 143–176, 1959.

Present paper is concerned with the following topics: an exposition of the theory of thermoelastic disturbances, the stresses produced in an infinite elastic solid by uneven heating, and the stresses produced in a half-infinite solid by uneven heating of the surface and by internal sources of heat. In particular, the following special problems are solved: the effect of a periodic line source, the effect of a moving line source, the stress due to an impulsive line source and to an impulsive point source (all problems for the infinite space), as well as the effect of a periodic line temperature applied to the surface of the half-space.

J. Nowinski, USA

5611. Manukyan, M. M., Thermal stresses due to exothermy of cement in blocks in the shape of slabs when taking into account the creep of concrete (in Russian), *Izv. Akad. Nauk ArmSSSR. Ser. Fiz.-Matem. Nauk* **11**, 2, 101–109, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6866.

In the study of P. I. Vasil'ev and M. A. Zubritskii [*Izv. Vses. N.-i. In-ta Gidrotekhn.* **56**, 1956] a graphoanalytical method is proposed for the determination of thermal stresses produced in concrete slabs because of exothermy of the cement. In the paper now being reviewed, these results are used and also the results in the theory of creep worked out by N. Zh. Arutyunyan ["Some questions in the theory of creep," Moscow, Gostekhizdat, 1952] to investigate the problems of stresses with consideration for the creep of concrete. As regards the stresses, the problem leads to integral equations of the second order of the Volterra type. Recurrent formulas are obtained for the stresses, on the basis of which graphs are drawn characterizing the changes of stress in the course of time.

M. A. Zadoyan

Courtesy Referativnyi Zhurnal, USSR

5612. Kvitka, A. L., Agarev, V. A., and Umanskyi, E. S., The solution of the axially-symmetrical problem of the theory of elasticity by electrical analogy for the case of the presence of centrifugal forces and temperature fields (in Russian), *Izv. Kievsk. Politekhn. In-ta* **19**, 455–461, 1956; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 9051.

A method of electrical analogy is recommended for the solution of the axially-symmetrical problem of the theory of elasticity,

founded on the analogy between the differential equations describing the deformation of an elastic body, and the potential distribution in a corresponding electrical model. The method is intended for the analysis of the stress condition in an elastic body of rotation under the action of an axially-symmetrical, superficial and three-dimensional (centrifugal forces) load and unsymmetrical heating setting up an axially-symmetrical temperature field. If only the superficial load is assumed to be acting, when the problem is described by simple, differential equations, the stresses are determined in relation to two stress functions, Ω and Φ, satisfying the following system of differential equations

$$\nabla_1^2 \Omega = 0, \; \nabla_1 \Phi^2 = \frac{\partial^2 \Omega}{\partial z^2}$$

where

$$\nabla_1^2 = \frac{\partial^2}{\partial r^2} - \frac{1}{r}\frac{\partial}{\partial r} + \frac{\partial^2}{\partial z^2}$$

In the general case, the equation of the stresses contains the functions Φ and Ω and the particular solutions of the corresponding complex equations, representing the action of centrifugal forces and unsymmetrical heating.

The system of differential equations for the functions Φ and Ω, represented in finite differences, is solved in a multiple-mesh electrical integrator with three resistance networks, modelling the region under investigation of the elastic body. The potentials in the junctions of the first network represent the values of the function Ω; those in the second network, the values of $\partial^2\Omega/\partial z^2$; and those in the third network, the values of the functions Φ; all integral function points of the second network being linked, through the source resistances, with the corresponding points of the third network. The boundary conditions for the functions Φ and Ω are satisfied by the method of stepwise approximation. No evaluation of the limits of error of the suggested method, nor any example of calculation for a concrete object, are furnished.

A. D. Kovalenko
Courtesy Referativnyi Zhurnal, USSR

5613. Zanaboni, O., Variational formulation of the elastic-plastic-viscous equilibrium (in Italian), *G. Gen. Civ.* **97**, 5, 322–330, May 1959.

The variational properties of the equilibrium configuration of a deformable body are established for finite displacement values and arbitrary stress-strain law. From physical considerations, author concludes that the transfer work, defined as the difference between the work performed by the external forces and the internal stresses, is a maximum when passing from one equilibrium configuration to another. E. Saleme, Argentina

Book—5614. Olszak, W., edited by, Non-homogeneity in elasticity and plasticity (Proceedings of the International Union of Theoretical and Applied Mechanics Symposium, Warsaw, Sept. 2–9, 1958), New York, Pergamon Press, Inc., 1959, xxiv + 528 pp.

For materials such as reinforced concretes or plastics and soils the nonhomogeneity of the elastic and plastic properties is evident and must immediately be taken into account for the design of structures. But it is also present in metals, as a consequence of the mechanical and thermal treatment or inhomogeneous temperature fields, and may have an important influence on their behavior. The technical significance of inhomogeneity is such that the theory of elasticity, plasticity and rheology deal intensively with the corresponding problems. The incentive for this work began with W. Olszak and his coworkers more than 20 years ago. Today, the well-known centers of pure and applied mechanics all over the world work on these problems. As this work covers a rather specialized branch, there arose the wish for a meeting of the scientists in this field to discuss the present state of research and further developments.

The IUTAM-Symposium served this purpose. 52 papers were submitted. These papers, published in the book, are classified in 6 groups: elasticity (120 p.), plasticity (175 p.), rheology (60 p.), dynamics and wave propagation (70 p.), statistical and micro-nonhomogeneity (55 p.), varia (30 p.). The discussions in the printed form are very short and give, except for some references to other papers, only the names of the contributors.

The papers concern themselves essentially with the theoretical treatment of the problems; experimental results are scarcely mentioned. They deal with the basic mathematical methods as well as with special problems, known from the elasticity and plasticity of homogenous bodies. The nonhomogeneity is often chosen in such a way that the basic equations can be solved. But, if also in real bodies it may be of another kind, the results are nevertheless valuable as they show generally the influence of nonhomogeneity. This may lead to results which are not only quantitatively but also qualitatively different from those obtained for homogeneous bodies.

Certain nonlinear homogeneous problems can be solved by using nonhomogeneous functions with free parameters, which may be chosen so that the real conditions are best approximated. The statistical method makes it possible to determine the statistical distribution of stress and strain on the different constituents with relatively simple and physically transparent mathematics.

As an assembly of original theoretical papers the book will be valuable to research engineers familiar with the mathematical methods and the interpretation of results. But there is no doubt on the significance of the results for the large group of engineers in practice. For these, survey papers would have been of special value, but the book contains only one such paper, that of W. Olszak and W. Urbanowski on plastic nonhomogeneity, written in an excellent manner. In his preface, the editor says he regrets that more such papers could not be obtained. But the book will surely contribute to making the relevant ideas and results known, and later these will be admitted in books of more practical aim or in textbooks. A. Kochendörfer, Germany

5615. Basheleishvili, M. O., The basic solutions of differential equations for an anisotropic elastic body (in Russian), *Soobshch. Akad. Nauk GruzSSR* **19**, 4, 393–400, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6608.

In the category of orthtropic bodies a sub-class can be isolated which possesses three linkages between the elastic constants, two of which are quadratic and one belongs to the third order. The system of three equations for the static state is merged with one equation of the sixth order, which is integrated by using the original integral setting. A system of solutions is found, having special features of the type $1/r$. In the particular case ($A_{44} = A_{55}$) Kroner's solution is obtained [E. Z. Kroner, *Physik* **136**, 4, 402–410, 1953]. A case is also examined of steady vibration with $A_{44} = A_{55}$. If one condition is imposed on the elastic constants

$$(A_{13} + A_{44})^2 = (A_{11} - A_{44})(A_{33} - A_{44})$$

then the matrix of the fundamental solutions is obtainable in a very clear form, but in the case where the condition remains unfulfilled the proposal is made to look for the corresponding functions by use of the method of the small perturbations.

I. S. Arzhanykh
Courtesy Referativnyi Zhurnal, USSR

5616. Rivlin, R. S., The constitutive equations for certain classes of deformations, *Arch. Rational Mech. Anal.* **3**, 4, 304–311, Aug. 1959.

Stress-strain-time relations of a similar nature to the one given in AMR **9** (1956), Rev. 3195 were derived on the assumption that deformation components all vary with time according to a specified law which is the same for each of the deformation components and

independent of the particle considered. Materials were considered to be initially isotropic and incompressible. Forces necessary to produce a simultaneous small extension and torsion in a circular bar were calculated. L. W. Hu, USA

Viscoelasticity

(See also Revs. 5611, 5614, 5616, 5626, 5667, 5790, 5797)

5617. Ree, F. H., Ree, T., and Eyring, H., Relaxation theory of creep of metals, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 1 (*J. Engng. Mech. Div.*), 41-59, Jan. 1960.

A dislocation model of secondary creep at high temperatures is put forward, viz. the dislocation is generated at a Frank-Read source, is held up on the slip plane "whenever certain bad sites lying in the dislocation encounter other bad sites on the opposite side of the slip plane," and proceeds again by diffusion of neighbors of bad sites "since the activation heat for creep equals that for self-diffusion." The bad sites are not specified in detail, but are thought to be impurities, alloying elements and other crystal imperfections. Application of straightforward rate-process theory to this model yields a good creep equation for aluminum, aluminum base alloys, and nickel. M. A. Jawson, England

5618. Davis, E. A., Relaxation of a cylinder on a rigid shaft, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 41-44, Mar. 1960.

Considering the material of the cylinder to be incompressible, equations are derived for the decrease in radial and tangential stresses in a cylinder shrunk on a rigid shaft. Plastic strain rates are assumed to be proportional to the nth power of stresses. Effects of strain-hardening and recovery are not considered but the speed-effect factor is considered for relaxation under the combined stress problem. A numerical example is worked out to illustrate the theory. P. G. Bhuta, USA

5619. Alexander, J. M., Approximate theory for the thermal and irradiation creep buckling of a uranium fuel rod and its magnesium can, *J. Mech. Engng. Sci.* **1,** 3, 211-222, Dec. 1959.

A simplified theory is developed for calculating the creep buckling of a fuel element, including both thermal and irradiation creep of the uranium, and thermal creep of the magnesium alloy can. This is made possible by introducing creep rate moduli for both uranium and can, analogus to Young's moduli for simple elastic buckling. The relationship between these rate moduli and the fundamental creep equations is discussed in detail and justification given for the proposal that the rate modulus should be defined as the slope of the stress-strain-rate curve at the mean stress. The theoretical interrelation between the results of sagging bar tests and the fundamental creep equations is also discussed.

From author's summary by L. W. Hu, USA

5620. Green, A. E., Rivlin, R. S., and Spencer, A. J. M., The mechanics of nonlinear materials with memory, Parts 1 and 2 (in English), *Arch. Rational Mech. Anal.* **1,** 1, 1-21, Sept. 1957; **3,** 1, 82-90, Mar. 1959.

The materials considered at the outset are such that the stress components at time t depend only on the displacement gradients at time t and at N previous instants in the interval $(0, t)$. The additional limitation is imposed that the stress is unaltered by a rigid-body rotation when the Cartesian reference system is rotated with the body. Further restrictions imposed by isotropy are also derived.

In Part I, N is allowed to tend to infinity, and certain functions are replaced by functionals. It is shown that these may be expressed to any desired approximation by the sum of a number of multiple integrals. Sufficient conditions on these integrals are obtained such that the stress-deformation relations are of hereditary type.

In Part 2 certain of the previous analytic requirements are relaxed. The stress is now allowed to have arbitrary polynomial dependence on the deformation gradients at the considered instant t, while its functional dependence on deformation gradients at preceding times need only be continuous in the open interval (not including t). R. Hill, England

Plasticity

(See also Revs. 5558, 5600, 5613, 5614, 5617, 5618, 5668, 5675, 5696, 5697, 5705, 5714, 5718, 5720, 5724, 5754, 5776, 5796, 5947)

5621. Hu, L. W., Design of circular plates based on plastic limit load, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 1 (*J. Engng. Mech. Div.*), 91-115, Jan. 1960.

Paper points out that for normal elastic analysis of flat plate in which strength is primary criterion maximum load determined is such that stress at no point exceeds the yield but that plate will support greater load if permissible plastic deflection is taken as criterion. Paper then gives basic equations and assumptions about failure theory and plastic flow rules on which analysis is based. The method of analysis is demonstrated by the full consideration of one particular case, and design charts are given which have been developed from similar analyses for nine different cases of loading and support. From these, one of plastic limit load, material yield stress, plate thickness or inner or outer diameters can be determined when the others are known.

Paper claims a more realistic basis for design, improved material utilization and better estimate of load-carrying capacity result from above analysis and also that errors are on safe side as proved both theoretically and experimentally. It is well known that membrane stresses which arise when a circular plate deforms increase its strength but allowance for this is not easy and above analysis may do this by another method. Reference is made to experimental results which indicated deflection under plastic limit load and elastic conditions to be of same order and hence not a governing factor.

Paper is of interest but of limited application as most stressing is governed by codes and author's technique cannot be used until it is approved and embodied in the codes. Reviewer considers that in fields free from such restrictions charts could well be used and as much supporting experimental evidence as possible assembled to verify theory and hasten its adoption in codes of practice.

A. F. W. Langford, Australia

5622. Perrone, N., Strain-hardening solutions to axisymmetric disks and tubes, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 45-53, Mar. 1960.

Solutions are obtained for annular disks and tubes made of a linearly strain-hardened material, loaded by a uniform tensile load on the outer boundary. The strain-hardening is assumed to follow a kinematic hardening flow law. In addition, a second solution for tubes which accounts for finite deformation is determined. Some numerical comparisons are made with existing isotropic hardening solutions. From author's summary by G. Gerard, USA

5623. Gryaznov, I. M., On the character of deformation in the plastic range, *Soviet Phys.–Doklady* **4,** 3, 683-686, Dec. 1959. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **126,** 6, 1250-1253, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

For materials which exhibit a yield point elongation or "plastic range" the following observations were made:

Within the "Chernov-Leuders" bands both crystallographic slip and grain rotation occur. The latter must be accompanied by slip.

Deformation after the yield point elongation causes a development of slip bands originally formed; that is, few new slip bands are formed as material strain-hardens.

For cold-worked and aged specimen, the slip bands formed during cold working are developed in subsequent extension, even though a new plastic range is present. M. J. Manjoine, USA

5624. Rzhanitsyn, A. R., Limiting equilibrium of reinforced concrete plates (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 12, 73-77, Dec. 1958.

For plates with the same reinforcement in two mutually perpendicular directions the yield condition is assumed in the form $(m)_{max} = m_T$, where m_{max} is the maximum bending moment and m_T the limit value of the moment. If the load is positive, the deflection surface must be a ruled surface. The plate under consideration is a polygonal plate on hinged supports along the contour, subjected to any positive load. Assuming that the angles of inclination of plate elements in directions perpendicular to the sides of the contour are small the author obtains the condition $S_i/l_i = m_T = \text{const}$, where l_i is the length of the ith side of the contour and S_i the moment of the load about this side. The criterion thus obtained is applied to certain particular cases. Thus, for instance, if the plate is loaded with a concentrated force, the destruction form will be that of a pyramid with the apex located at the point of attachment of the force. In the case of curvilinear contour the plate may be represented in the form of a series of infinitesimal faces of a polyhedron. It is pointed out that if this criterion is used, the possibility of a destruction, such that only part of the plate bounded by a closed line is deformed, should be taken into consideration. Finally the author discusses the possibility of applying to metal plates the computation method of reinforced-concrete plates according to the limiting equilibrium.

W. Wierzbicki, Poland

5625. Ol'shak, V., On the foundations and applications of the theory of nonhomogeneous elasto-plastic media (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 20-34, Aug. 1957.

Paper is based on an earlier paper of author on the application of conformal representation to elastic plane problems [*Ing. Arch.* **6**, p. 402, 1935]. Author assumes a material homogeneous in elastic range but inhomogeneous in plastic range. The yield point depends on the coordinates of the points in the body. The eccentric slotted cylinder is treated under internal and external pressure as well as under a force normal to the slot. From stress functions the stresses in cylinder are derived for the elastic, plastic and elastic-plastic problems. A cylindrical boundary is assumed between the elastic and plastic zone. The radius of this boundary is calculated from a transcendent equation.

Another example is the problem of plane deformation of semi-infinite body with a circular hole.

H. Mussmann, Germany

5626. Vakulenko, A. A., A thermodynamic investigation into the relation between stress and deformation in isotropic elastoplastic media, *Soviet Phys.-Doklady* **4,** 3, 697-700, Dec. 1959. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **126,** 4, 736-739, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

In two earlier papers (unavailable to the reviewer), author showed that on the basis of the first and second laws of thermodynamics and Onsager's principle, together with the decomposition of total strain into elastic and plastic components, there exists in an elastoplastic medium a Helmholz free-energy density function, whose arguments are the elastic strain tensor components, the absolute temperature, and a set of thermodynamic properties, λ_1, $\lambda_2 \ldots \lambda_n$, whose changes reflect the history of prior inelastic deformation of the material.

Present paper utilizes this result to derive general rheological equations for materials whose thermodynamic properties are not changed by plastic deformation per se ($d\lambda_1 = d\lambda_2 \ldots d\lambda_n = 0$) as well as for those where the change in property can be described by a single parameter, i.e. the total plastic work performed ($d\lambda_1 = dWp$, $d\lambda_2 = d\lambda_3 \ldots d\lambda_n = 0$). Under the conditions mentioned for macroscopically isotropic materials, a general equation is found which gives each deviatory stress-tensor component as a quadratic function of the corresponding component of the plastic-strain-rate tensor. (This equation, Eq. [8] of the translation, contains a misprint in the second term of the right-hand side.) It follows also that the principal axes of the stress tensor and of the incremental strain tensor coincide.

With the additional assumptions that plastic flow is incompressible and that the invariants of the stress tensor are not functions of the second invariant of the plastic-strain-rate tensor, one can show that the general equation does not contain time explicitly, that it describes implicitly a yield condition or a hardening law, and that it establishes the existence of a Mises-Prager plastic potential function. Moreover, if one assumes the yield condition of von Mises, the general equation leads to the Prandtl-Reuss theory of elastoplastic flow. K. N. Tong, USA

5627. Yoshimura, Y., Hypothetical theory of anisotropy and the Bauschinger effect due to plastic strain history, Aero. Res. Inst., Tokyo Univ., Rep. 349, 221-247, Nov. 1959.

This is an interesting and important contribution to plasticity theory. Author has formulated a theory in which anisotropy and the Bauschinger effect, as well as work-hardening, are correlated with previous strain history, taking account of both contra- and covariant components of the stress tensor. If I is the spherical unit tensor of second order, T' the deviatoric stress tensor, E a tensor representing the strain history, then the yield function for the anisotropic state resulting from the strain history E is obtained from $I + AE$ and T' in the same way as the yield criterion of von Mises is obtained for the isotropic state from I and T', A being a scalar coefficient dependent both on the work-hardening and strain history. The Bauschinger effect is introduced into the yield criterion as a term of the form $BE..T'$, where B is a scalar generally dependent on E, and the two dots signify the double scalar product of two dyadics.

The author then analyses both his own and the classical experiments of Taylor and Quinney and shows that certain of the deviations of these experimental results from the predictions of the theory of von Mises may be explained by his theory.

J. M. Alexander, England

Rods, Beams and Strings

(See also Revs. 5616, 5668, 5669, 5682, 5683, 5694, 5744, 5768, 5774, 5783, 5797, 6043)

Book—5628. Kachurin, V. K., Flexible ropes with small supporting points (in Russian), Moscow, Gostekhizdat, 1956, 224 pp. 7r 40k; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6972.

This is an investigation of filaments with small supporting points: single-span, multi-span, double-banded chains made up of stiff disks and their combinations with the filaments. The equations for the curve of the suspension of the filament with a vertical load are expressed through the deflection moments in a simple beam of the same span, while the length of the filament is expressed through the transverse forces. Both vertical and horizontal loadings are considered. Some more precise calculations are examined in the form of taking into account elongations, consideration of the stiffness of the filament in deflection, and so forth. The

book contains a large number of examples. A short survey is given of the existing literature. V. A. Kiselev

Courtesy Referativnyi Zhurnal, USSR

5629. Glazamitskaya, S. M., The toughening of cord by the method of gradual tensioning by means of decreasing loads (in Russian), *Izv. Vyssh. Uchebn. Zavedenii, Tekhnol. Tekstil'n. Prom-sti* no. 3, 26–33, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 7074.

The possibility is experimentally confirmed of the improvement of cotton threads by the application of progressively diminishing loads, similar to the method used for removing the over-stresses of cellulose hydrate filaments. This opens the way for widening the theory of the toughening of artificial fibers and the practical means of achieving this object for cotton cords as well.

A. N. Gerasimov

Courtesy Referativnyi Zhurnal, USSR

5630. Solov'ev, A. N., The influence of twist and the number of folds on the properties of the twisted yarn (in Russian), *Izv. Vyssh. Uchebn. Zavedenii, Tekhnol. Tekhstil'n. Prom-sti* no. 3, 7–19, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 7077.

An experimental investigation was carried out on the change of properties of twisted cotton yarn in relation to the number of turns, the size and direction of twist of the threads. The samples of the simulated twisted yarn were prepared on the usual type of torsion meter. It was shown that the changes of the fundamental characteristics (torque, rupture length and rupture elongation) of the simulated and ordinary twisted yarn proceed in identical fashion. Formulas are given for designing the basic properties of twisted cotton yarn. A. V. Matukonis

Courtesy Referativnyi Zhurnal, USSR

5631. Frisch-Fay, R., On large deflections, *Austral. J. Appl. Sci.* **10,** 4, 418–432, Dec. 1959.

It is known that large deflections of beams can be discussed by taking the linear relation $M = EI/R$, and the exact value of the radius of curvature R in place of the approximate value d^2y/dx^2. The deflections can be expressed in terms of elliptic function of the first and second kind. The author obtains the numerical value of deflections in a number of cases. He defines the critical load as the load which when released allows the beam to assume its straight form. It is also shown that while the classical theory gives the straight form as the only possible position of unstable equilibrium, the finite deflection theory gives a stable position with a definite lateral displacement.

The particular cases worked out include the double loop, the single loop with the ends going to infinity and the case of the cantilever with the load acting in any direction. In the last case the horizontal movement of the end of the cantiliver is toward the fixed end, and hence the vertical deflection is found to be less than that given by the classical theory.

For the loop cases discussed it is clear that the classical relation $M = EI/R$ should be modified to include higher degree terms in (I/R). [See B. R. Seth, Proc. Symp. Appl. Math., **3,** McGraw-Hill Book Co., Inc., 1950, pp. 67–84.]

B. R. Seth, India

5632. Chakravorti, A., Flexure of a composite beam whose section is bounded by intersecting arcs of nonconcentric circles, *J. Technol., Calcutta* **3,** 2, 99–108, Dec. 1958.

Author takes the classical stress equations for a composite cantilever beam with a concentrated load at one end and evaluates the harmonic functions in these equations for the symmetrical case of two materials with different moduli of elasticity.

B. E. Gatewood, USA

5633. Legendre, R., Stress distribution in a circular ring (in French), *C. R. Acad. Sci., Paris* **249,** 13, 1084–1086, Sept. 1959.

5634. Mizuno, M., Problem of large deflection of coiled springs, *Bull. JSME* **3,** 9, 95–103, Feb. 1960.

A coiled spring with uniform pitch and straight central line in its undeformed state is buckled under a pressure acting on both hinged ends. Determination of the (finite) deformation. The differential equation of the problem is integrated by means of elliptic integrals, the solution being a generalization of the classical elastica of a thin rod. The theoretical results are in satisfying accordance with the experiments made by the author.

O. Bottema, Holland

Plates, Shells and Membranes

(See also Revs. 5606, 5609, 5621, 5624, 5675, 5676, 5677, 5678, 5680, 5689, 5690, 5691, 5692, 5694, 5702, 5722, 5745, 5783, 5786, 6042)

5635. Tunell, T., Circular plate with concentric circular holes uniformly loaded and supported at outer and inner edges (in Swedish), *Nordisk Betong* **4,** 1, 51–58, 1960.

Using theory of elasticity and assuming deformation to be infinitesimal and Poisson's ratio to be zero, author deduces formulas for radial and tangential moments and for shear forces under the following boundary conditions: (a) all edges simply supported; (b) all edges built-in; (c) exterior edge simply supported and interior edge built-in; and (d) exterior edge built-in and interior edge simply supported.

The maximum values of moments and shear forces are plotted for various ratios of interior to exterior radius of the boundary.

S. T. A. Odman, Sweden

5636. Chen, M. M., and Hsu, P. T., Stress functions for plates bounded by piecewise analytic curves, *J. Aero/Space Sci.* **27,** 3, p. 240 (Readers' Forum), Mar. 1960.

5637. Nakahara, I., and Koizuma, T., Transverse bending of an infinite plate with a cylindrical circular hole by the three-dimensional theory of elasticity, *Bull. JSME* **3,** 9, 66–71, Feb. 1960.

For the case of pure bending about one axis, the problem described in the title is solved by superposition. The stress state for pure bending and one other simple stress state are combined with a state described by an infinite series of modified Bessel and trigonometric functions and a state given in the form of an integral. The condition of zero stress around the hole yields an infinite set of linear equations for the coefficients of the infinite series. The solutions of the truncated system converge rapidly, so that accurate results can be obtained with six terms.

Valuable numerical results show the stress-concentration factor as a function of the ratio of hole diameter to plate thickness. In the case of small holes, this factor is found to be larger than that predicted by thin-plate theory but smaller than that predicted by E. Reissner [*J. Appl. Mech.* **12,** p. A69, 1945].

E. H. Dill, USA

5638. Keshava Rao, M. N., Bending of thin rectangular plates with edge beams, *ASME Trans.* **81** E (*J. Appl. Mech.*), 4, 686–688 (Brief Notes), Dec. 1959.

Note indicates how analysis of Fletcher and Thorne [AMR **8**(1955), Rev. 3690] may be extended to case of thin plate with edge beams of different flexural and torsional rigidities. Details of complete calculation are not given but above reference is given for method of doing it. J. Fulton, Scotland

5639. Schumann, W., and Martinola, M., Theoretic and experimental study of the distribution of tangential stresses in circular plates of variable thickness (in French), *C. R. Acad. Sci., Paris* **249,** 17, 1608–1610, Oct. 1959.

5640. Kmita, J., Influence surfaces and moments of skew slabs (in Polish), *Inzyn. Budown.* **16,** 8, 321–329, Aug. 1959.

5641. Saito, A., Kimura, S., and Shimazaki, T., Bending of elliptic plates under a concentrated load, *Bull. JSME* **2,** 6, 299–305, May 1959.

Title problem with clamped or simply supported boundary conditions is solved by the method used in a previous paper by A. Saito [Proc. 7th Japan Nat. Congr. for Appl. Mech., 1957]. The solution is given in the form of infinite series. The plate may or may not have a confocal elliptic hole.

The arbitrary constants in the plane biharmonic function are determined by expanding the particular solution expressed by elliptic coordinates into Fourier series and by using the boundary conditions.

As a numerical example a clamped elliptic plate under a concentrated load at the center is treated.

G. C. K. Yeh, USA

5642. Streis, E., Cantilever plate subject to a concentrated load (in German), *Bautechnik* **36,** 2, 62–68, Feb. 1959.

Deflections, moments and shear forces are computed by means of finite differences in a rectangular cantilever plate loaded by a concentrated force applied at the free edge at three different locations (middle, quarter point and corner of the free edge). The results for the plate loaded at the middle are in good agreement with those obtained by MacGregor [*Mech. Engng.*, Apr. 1935] for an infinitely long plate. C. E. Massonnet, Belgium

5643. Werfel, A., On boundary conditions in the bending of thin elastic plates (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 287–296, 1959.

Paper concerns the number of force boundary conditions available in plate theory. Author compares stresses of plate and Saint-Venant torsion theory in special case of a uniformly twisted plate, then argues that, for plate bending in general, three force conditions may be satisfied by means of a boundary perturbation involving shearing forces which act at a small but unspecified distance from edge. The criticisms of Reissner's theory on the effect of shearing stress are, in reviewer's opinion, unfounded as they relate to questions of relative magnitudes and not to general principles of the theory. L. Maunder, Scotland

5644. Lur'e, A. I., and Prokopov, V. K., Calculations for the forces eccentrically supporting a loaded plate (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 192, 36–42, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6615.

A method is demonstrated of the calculation for forces transmitted to a sphere through a plate eccentrically loaded by a concentrated force; the deformation of the plate itself is not taken into account in the calculation. This statically indeterminable problem has this special feature that the forces acting on the sphere Q_m and the deflection of the plate at the very same place S_m are linked together by the relation

$$S_m = \kappa\, Q_m^{3/2}$$

where κ is the coefficient depending on the elastic properties and dimensions of the sphere, m the sphere's number. By making use of Castigliano's generalized theorem the authors succeed in obtaining for the unknown forces a system of nonlinear algebraical equations, which in the end merges into one equation. Using the interpolational formula

$$(1 + x^{2/3})^{3/2} = 1.065 + 1.948\,x \quad (0 < x < 1) \qquad [\bullet]$$

the authors merge the solution of the problem under consideration with the solution of a monolinear algebraical equation. The derivation of the interpolational formula [•] is given in a supplement to the paper. V. I. Mossakovskii

Courtesy Referativnyi Zhurnal, USSR

5645. Saxonov, R. M., Calculations for hexagonal slabs for road surfacing (in Russian), Sb. Inform. Soobshch. o Nauchno-Issled. Rabotakh. Vypolnen. Vyssh. Uchebn. Zavedeniyami (Collection of communications of information on the scientific research work carried out by the higher educational institutions), Stroit. Konstruksii, Kiev, 1958, 58–59; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6722.

The problem is solved for the deflection of a hexagonal slab on an elastic semispace. The area of contact of the slab with the foundation is divided into 37 portions. The soil pressure inside each portion is assumed to be constant. Equations are derived for the deflection of the slab in terms of finite differences for the centers of the portions the slab has been divided into. The settlements of the soil due to the action of the stepped curve of an unknown load on the soil are determined in the centers of the portions. By equalizing the deflections of the slab in the centers of the portions with the settlements of the soil the author succeeds in obtaining a system of algebraical equations. In addition, the conditions of equality to zero are also calculated for the deflection moment and the full running load on the edge of the slab and for the equation of equilibrium of all the forces applied to the slab. As the result of the calculations the author is able to make the following deductions: (1) The hexagonal slab centrally loaded can be looked upon with sufficient accuracy as being round. (2) When the load is placed in the corner of the plate a significant reactive pressure is developed under the plate, four times larger than the pressure on the same portion produced by a central load; under the opposite corner a negative pressure is developed, twice as large as the given pressure of central loading.

V. I. Mossakovskii

Courtesy Referativnyi Zhurnal, USSR

5646. Popov, G. Ya., Deflection of a semiinfinite plate with combined elastic foundation, *Soviet Phys.-Doklady* **4,** 3, 692–696, Dec. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **126,** 3, 534–538, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Highly mathematical paper considers deflection of a semi-infinite plate on an elastic half-space covered by springs. Use is made of integral and functional equations and author refers to equations derived by Korenev, AMR **5**(1952), Rev. 66.

E. H. Mansfield, England

5647. Tsien, C. H., Numerical solution of elastic foundation (in Russian), *Scientia Sinica* **7,** 5, 552–563, May 1958.

5648. Gallotly, G. D., Edge influence coefficients for toroidal shells of positive Gaussian curvature; Edge influence coefficients for toroidal shells of negative Gaussian curvature, *ASME Trans.* **82** B (*J. Engng. Indust.*), 1, 60–75, Feb. 1960.

Author presents edge influence coefficients for thin toroidal shells with positive curvature and constant thickness and with negative curvature and constant thickness. Analyses are based on elastic small-deflection theory. Results are obtained for internal pressure, edge shear, and edge bending. Numerical values are tabulated for wide ranges of thickness ratio as well as ratio of major radius to minor radius of the torus.

R. E. Miller, USA

5649. Kornecki, A., Symmetrical deformation of a thin toroidal shell of elliptical cross-section, *Bull. Res. Council Israel* **7** C (Technology), 1, 1–10, Apr. 1959.

This paper presents an approximate computation method of stress and strain components in a thin-walled toroidal elastic shell of el-

liptical cross section, limited by two parallels and loaded arbitrarily but symmetrically with respect to the axis of revolution. Making use of Meissner's variables and neglecting small terms, the problem is reduced to the determination of a complex function satisfying a differential equation with suitable boundary conditions. Applying asymptotic methods of integration the solution is found in closed form.

From author's summary by Z. Hashin, USA

5650. Galletly, G. D., Torispherical shells—A caution to designers, *ASME Trans.* **81** B (*J. Engng. Industry*) 1, 51–66, Feb. 1959.

It has recently become apparent, through a rigorous stress analysis of a specific case, that designing torispherical shells by the current edition of the ASME Code on Unfired Pressure Vessels can lead to failure during proof-testing of the vessel. The purpose of the present paper is to show in what respects the Code fails to give accurate results. As an illustrative example, a hypothetical pressure vessel with a torispherical head having a diameter-thickness ratio of 440 was selected. The supports of the vessel were considered to be either on the main cylinder or around the torus. The vessel was subjected to internal pressure and the elastic stresses in it were determined rigorously and by the Code. A comparison of the two revealed that the Code predicted stresses in the head which were less than one-half of those actually occurring. Furthermore, the Code gave no indication of the presence of high compressive circumferential direct stresses which exceeded 30,000 psi for practically the entire torus. If the head had been fabricated using a steel with a yield point of 30,000 psi, then a limit analysis shows that it would have failed or undergone large deformations, whereas the Code would have predicted that it was safe. The Code's rules for torispherical heads are thus in need of revision for certain geometries. The implications of the foregoing results are currently being studied by the ASME; in the interim, however, designers should exercise care in applying the Code to torispherical shells.

It is also shown in the paper that the use of the membrane state as a particular solution of the differential equations is not a good approximation for toroidal shells of the type considered.

From author's summary by J. H. Baltrukonis, USA

5651. Massonnet, Ch., Orthotropic plates and orthotropic cylindrical shells with asymmetric ribs (in French), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 201–230, 1959.

Author develops the theory of plates consisting of an isotropic slab reinforced by two orthogonal series of ribs fixed to one side of the slab. He shows that in a structure of this kind the transverse displacement w follows an eighth-order equation. It is impossible to find a Huber fourth-order equation which represents strictly, for all cases of loading, the behavior of the actual plate. On the other hand, it is possible to find, for a given case of loading, a Huber plate which is equivalent, on an average, to the actual plate. The author shows how it is possible to determine the rigidities of this Huber plate for the case where the plate being studied is very wide and forms a multi-girder bridge. He shows that the value for the apparent torsional rigidity suggested by Giencke [AMR **9**(1956), Rev. 1051] is excessive.

The foregoing theory is extended to cylindrical shells stiffened by two orthogonal series of ribs fixed to one side of the shell. The general equations obtained will be applied to concrete cases in a subsequent paper.

From author's summary by E. Monch, Germany

5652. Dulacska, E., Toroidal and spherical shells with rectangular plan projection (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **26,** 3/4, 349–356, 1959.

Consider a toroid whose axis of revolution (the x axis) is horizontal. Let r be the radius of its circular cross section, R that of its center line. (For $R = 0$ this includes the case of a sphere.) The z-axis points vertically upward. From this toroid the middle surface of a shell is cut by two planes $x = \pm a$ (with $a < r$) and two planes $y = \pm b$. The author formulates the differential equation for the stress function of the membrane stress problem and solves it by collocation. Numerical example is given.

W. Flugge, USA

5653. Turner, C. E., Study of the symmetrical elastic loading of some shells of revolution, with special reference to toroidal elements, *J. Mech. Engng. Sci.* **1,** 2, 113–129, Sept. 1959.

After a brief review of previous work, author derives the equilibrium and deformation equations obtaining two general expressions which are applied to toroidal shells where the radius of revolution is much larger than the radius of the ring cross section. The two simultaneous differential equations are special cases of the Mathieu type.

The theory is applied to the analysis of: (a) meridional bending moment and circumferential force in flat-plate bellows with tensile load, and a torispherical pressure vessel head; (b) meridional stresses and circumferential strains in corrugated pipe bellows with compressive loadings. In these cases, calculations and measured strains are in good accordance.

An appendix gives tabulated solutions.

A. M. Guzman, Argentina

5654. Turner, C. E., Stress and deflection studies of flat-plate and toroidal expansion bellows, subjected to axial, eccentric or internal pressure loading, *J. Mech. Engng. Sci.* **1,** 2, 130–143, Sept. 1959.

An experimental investigation is carried out on corrugated-pipe and flat plate bellows subjected to the title loadings. A comparison is given of experimental and theoretical results of the author (see previous paper), who in appendix develops an approximate theory for stresses in certain flat-plates bellows. Detailed discussions and design applications are interesting.

A. M. Guzman, Argentina

5655. Holand, I., An application of Donnell's theory of circular cylindrical shells to the analysis of curved edge disturbances (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 65–80, 1959.

The relations between forces and displacements in the Donnell theory are given, and the differential equations of the shell are deduced. This theory is used for a Fourier analysis of edge disturbances from the curved edge. By a further analytical treatment of the solution all statical quantities are expressed in closed form by the edge quantities at one disturbing edge. Edge disturbances from two edges may be treated by superposition. Matrix notation is used to simplify the formulas. From author's summary

5656. Lee, S. L., Bending of partially loaded simply supported cylindrical shells (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 155–168, 1959.

An explicit solution for partially loaded cylindrical shells simply supported along the transverse edges and the longitudinal edges is presented. The solution is obtained by the representation of the displacement components and the load components in the forms of double trigonometric series. Therefore its validity is limited to those loadings for which the series involved are convergent. Some of these cases are treated in detail.

In order to simplify the expressions involved in the solution, the value of Poisson's ratio is assumed to be zero, although its retention presents no fundamental difficulty.

While no details are given, the solution for partially loaded cylindrical shells with various longitudinal edge conditions and simply supported along the transverse edges is also discussed.

From author's summary

5657. Fradlin, B. N., and Shakhnovskii, S. M., On the derivation of integro-differential equations for the equilibrium of slanting shells (in Russian), *Dokladi Akad. Nauk URSR* no. 4, 381–385, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6646.

The problem on the equilibrium of a slanting shell with an arbitrary load merges with the investigation of a system of functional equations. A method is demonstrated for the derivation of nuclei and operators entering these equations. An example is examined of the calculations for a hinge-supported slanting shell, rectangular in plane, under the action of an evenly distributed load.

From authors' summary

Courtesy Referativnyi Zhurnal, USSR

5658. Len'ko, O. N., Strength of orthotropic cylindrical shells (in Russian), Calculations for three-dimensional constructions (Raschet Prostranstv. Konstrukstsii no. 4), Gosstroiizdat 1958, 499–524; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6648.

The strength is investigated of an orthotropic cylindrical panel when compressed along the generatrix by forces evenly distributed on its curved edges. It is assumed that the panel is hinge-supported on all the edges by stiff ribs. The problem is solved in a nonlinear setting with the aid of the energy method. In order to simplify the investigation the case of a square panel is examined first. The bulges are taken to be circular. The flexure is presented in the following form

$$w = f_1 \sin \frac{m\pi x}{a} \sin \frac{m\pi y}{a} + f_3 \sin^3 \frac{m\pi x}{a} \sin^3 \frac{m\pi y}{a}$$

where f_1, f_3 are constants; a is the length of the semi-wave; x, y are the axial and peripheral coordinates respectively. Then a more precise solution is given in which account is taken of the ellipticity of the bulges. The correlations obtained open up the possibility of calculating the value of the upper p_u and the lower p_l of the critical stresses, with the elastic properties of the material and the geometrical parameters of the panels known. An example is given for the calculation of p_l for one sample. The results of the calculations are compared with the experimental data.

F. S. Isanbaeva

Courtesy Referativnyi Zhurnal, USSR

5659. Adams, E., Increased stresses in the disks of rotors caused by the blades (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 306–316.

From equilibrium and stress-strain considerations in an elastic disk of variable thickness the equation for Airy function is derived in the case of plane stress state. Equation can be solved in closed form for two elementary cases: when the disk thickness is constant or when it varies as the inverse square of the radius. In both cases the variation of stress distribution in the circumferential direction is small if the blade number is high (> 10). On the other hand, higher-order terms of the circumferential angle can be neglected if the blade number is small. Basic equations can be simplified considerably when the thickness variation with radius is moderate. Any disk can also be taken as consisting of two or more concentric disks the thickness distribution of which corresponds to one of the two above-mentioned elementary cases. General results are illustrated by 25 diagrams and more extensive calculations are given in three appendixes.

A. A. Kuhelj, Yugoslavia

5660. Gram, A. J., Mechanical design of heat exchangers, *Indust. Engng. Chem.* **52,** 6, 468–473, June 1960.

5661. Kranzke, M. A., and Short, R. D., Graphical method for determining maximum stresses in ring-stiffened cylinders under external hydrostatic pressure, David W. Taylor Mod. Basin Rep. 1348, 11 pp., Oct. 1959.

Calculation of the maximum stresses in a ring-stiffened cylinder subjected to external hydrostatic pressure, using the analysis of V. L. Salerno and J. G. Pulos [Polytechnic Inst. of Brooklyn Aero. Lab. Rept. no. 171-A, June 1951], is facilitated by curves presented by the authors.

From authors' summary by G. B. Warburton, Scotland

5662. Reissner, E., On finite bending of pressurized tubes, *ASME Trans.* **81** E (*J. Appl. Mech.*), 3, 386–392, Sept. 1959.

Author investigates nonlinear behavior in bending of straight or curved tubes, taking into account the effect of internal pressure. It is shown that Brazier's well-known theory for straight tubes, extended by Wood [*J. Appl. Mech.* **25,** 453–458, 1958; AMR **12**(1959), Rev. 5462] for the effect of internal pressure, may be considered as a first approximation, in so far as expansion in powers of a suitable parameter is established, and corresponding second approximation is obtained. It appears that critical bending moment in this second approximation is about 10% smaller than according to Brazier and Wood. Nonlinear corrections to the well-known linear theory of originally curved tubes are also considered; these corrections appear to be negligible if the ratio of the change of curvature to the initial curvature is small compared to unity. Finally, the theory of Brazier and Wood for the first approximation to the nonlinear behavior of an originally straight tube is extended to tubes with slight initial curvature.

W. T. Koiter, Holland

5663. Poverus, L. Yu., Stability of the equilibrium of an elastic shell of rotation of small positive curvature of the type of a truncated cone, which is being subjected to an evenly distributed external pressure (in Russian), *Trudi Tallinsk. Politekhn. In-ta* (*A*) no. 129, 16 pp. + illus., 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6647.

An investigation is carried out on the problem described in the title. The differential equations for local stability are solved by means of the Bubnov-Galerkin method, when the function of deflection is obtained in the first approximation in the form: $\bar{w} = a \sin m\pi\xi$ and in the second approximation in the form: $\bar{w} = a_1 \sin n\pi\xi + a_2 \sin 2_m\pi\xi$, where a, a_1 and a_2 are certain constant parameters. The integration is carried out by the numerical method for one special case for the shell (with $n = 3.5$); an expression is obtained for the critical load. A comparison is made, using the same case of the critical loads for a symmetrical shell of small positive curvature and for a cone-shaped shell; it was established that the conicity of the shell has little influence on the magnitude of the critical pressure. The post critical form of equilibrium is investigated by the energy method for a shell with $n = 3.5$; relations are given of the potential energy Π to the critical load and the coefficients $a_1 a_1$ and a_2. A comparison is made of the ratio Π/Π_0 (where Π_0 is the potential energy of the initial stressed state) for a cone-shaped shell and for cylindrical and symmetrical shells; it is established that the relative energy barriers, separating the stable states of equilibrium at subcritical pressures are magnitudes of single order.

P. I. Zheludev

Courtesy Referativnyi Zhurnal, USSR

5664. Czerwenka, G., Contribution to the statics of circular wings (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 316–325.

Using Flügge's basic differential equation of equilibrium, theoretically the stresses might be computed. For practical solutions, however, a method of superposition has been introduced by the author, which is based on the use of the following fundamental systems: (a) Annular frame for external loads in oval form, (b) membrane for external forces producing shear stresses, (c) "Ebner-Köller shearing field" for longitudinal forces, (d) pressure-vessel for rotational symmetrical loads. Double-skin shells can be treated

in the same manner. In many cases it is necessary to connect the external shell with the internal shell by means of a longitudinal stiffener system. The solution in this case is based again on Ebner-Köller's extended field assumption. The strain in the transverse direction has been neglected, following Girkmann's simplifying assumption. Reviewer believes that by neglecting the shear deformations the basic differential can also be solved, without extensive work and without the sacrifice of the accuracy of the solution. R. Szilard, USA

5665. Sato, Y., A comparison between experiments and Nakanishi's theory on the yield point of mild steel cylinders under internal pressure, *Bull. JSME* **2,** 8, 504–508, Nov. 1959.

Internal pressure was applied to eight hollow-cylinder specimens all of roughly the same OD (0.7 in.) but of ID varied to give wall-thickness ratios (γ = OD/ID) from 1.1 to 2.2. The test section was reduced from larger stock over a length of about 3.5 in. Specimen material was 0.39% plain carbon steel in annealed (850°C) condition having a lower yield shear strength of about 18 ksi. Maximum shear stress at yielding of the ring section, as detected by tangential strain measurement, increases with γ up to 1.55. Above this value of γ it levels off at a value 1.5 times the lower yield shear strength. For the thicker tubes, the pressure versus tangential strain diagram continues to rise after the yield, a plateau corresponding to Luders strain propagation being reached only after considerable plastic strain. The upper yield point disappears when γ exceeds 1.5, a further indication of the radial nonuniformity of stress in the thicker cylinders. J. M. Krafft, USA

5666. Holmes, M., Stiffened plating under transverse load, *Quart. J. Mech. Appl. Math.* **12,** 4, 443–453, Nov. 1959.

The behavior of a flat plate stiffened by beams is analyzed by Fourier series and solutions are obtained for symmetrical and antisymmetrical forms of loading. Approximate solutions (assuming infinite torsional rigidity of the beams) may be obtained for a wide variety of loading forms. The results of tests carried out on several small-scale stiffened plate structures confirmed validity of the above analysis and the assumptions on which it is based.
G. Sonntag, Germany

5667. Yu, Y.-Y., A new theory of sandwich plates—general case, AFOSR TN-59 1163 (Polyt. Inst. Brooklyn, Dept. Mech. Engng. TN-6), 27 pp., Nov. 1959.

A two-dimensional theory for an elastic sandwich plate is presented. The theory is valid for any symmetrically arranged, three-layered plate with isotropic or orthotropic core. Stress, strain, and displacement equations are derived for static conditions and equations of motion for dynamic conditions involving wide frequency ranges. For sandwiches with very thin faces and for limited frequency ranges, simplified equations are offered. Finally the case of a sandwich plate with a thin viscoelastic core is briefly discussed. J. D. Marketos, USA

5668. Heyman, J., Inverse design of beams and grillages, *Proc. Instn. Civ. Engrs.* **13,** 339–352, July 1959.

A deflection equation for the structure is assumed which satisfies all boundary conditions. Curvatures are computed by double differentiation of the deflection equation, and the flexural rigidity at a particular cross section is related to the external loading by means of the bending moment. This method, which leads to an optimum design, covers both elastic and plastic design, and it is presented first with reference to beams, then it is generalized to include two-dimensional structures loaded transversely (plane grillages). Two numerical examples illustrate the use of the method. J. D. Marketos, USA

5669. Banerjee, K. K., and Basole, M. M., On analysis of built-up slabs, *J. Technol.* **3,** 2, 119–136, Dec. 1958.

By a "built-up slab" authors mean a side-by-side arrangement of thin strips, each supported at its ends, with continuity of displacement across the side edges of the strips, but with no constraint on transverse slopes. A laterally loaded slab of this type is analyzed by assuming elementary beam bending and torsion theory, expanding the deflection and rotation of each strip in a Fourier series, and imposing the appropriate continuity conditions. With simply supported ends, the Fourier coefficients within each strip decouple, and, with N strips, the determination of the n^{th} Fourier coefficient in each strip requires the solution of $N-1$ simultaneous equations. The results of experiments on reinforced-concrete slabs are compared with analytical results found by this approach, and good agreement is exhibited.
B. Budiansky, USA

5670. Protasov, G. E., Experimental investigation of a round plate reinforced by an annular stiffening rib (in Russian), Strength calculations (Raschetyi va Prochnost', no. 3), Moscow, Mashgiz, 1958, 122–132; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6666.

Experimental data are furnished for the determination of deformations and stresses in a round freely supported plate, reinforced by a single annular stiffening rib and loaded by an evenly distributed load. As could be expected, the experimental data give excellent confirmation, within the limit of elastic deformations, of the results of the theoretical calculations. K. A. Kitover
Courtesy Referativnyi Zhurnal, USSR

5671. Wallin, L., Large deflections of non-linear elastic rectangular plates (in English), *Ark. Fysik* **17,** 4, 89–95, 1960.

A strain energy method is used to obtain an approximate expression for the deflection of an initially plane rectangular plate acted on by uniform transverse pressure. No account is taken of bending stresses. Displacements are represented by polynomials. It is assumed that the plate material is such that in a test piece strain is proportional to the nth power of the stress.
D. M. A. Leggett, England

5672. Girkmann, K., and Beer, R., Application of the exact Reissner theory to orthotropic plates (in German), *Öst. Ing.-Arch.* **12,** 1/2, 101–110, Nov. 1958.

The aim of the paper is to construct the equations of the theory of orthotropic plates, which account for the influence of shear on the deflection; corresponding results for isotropic plates were derived by E. Reissner [*J. Appl. Mech.* **12,** A69–A67, 1945]. The present authors however apply the method proposed by M. Schäfer [*ZAMM* **32,** 161–171, 1952; AMR **6**(1953), Rev. 809]. Assuming parabolic distribution of shear stresses along the plate thickness and rejecting the third equilibrium equation, authors arrive at three independent partial differential equations of sixth order for resulting deflection and shear forces. The equations are identical except for the right-hand sides; they enable us to satisfy three boundary conditions. As an example the authors solve a simply supported plate strip, the load being constant over the whole surface of the strip. W. Urbanowski, Poland

5673. Gerard, G., Minimum weight analysis of orthotropic plates under compressive loading, *J. Aero/Space Sci.* **27,** 1, 21–26, 64, Jan. 1960.

Author compares structural efficiency of unstiffened flat plates, plates with longitudinal or transverse stiffeners only, and plates with waffle-grid stiffening systems for use as compression covers of multi-cell box beams. Beams are loaded in bending without torsion. Analysis is based on orthotropic plate theory with the assumption that optimum design results when various buckling modes occur simultaneously. Stiffeners are considered to be rectangular in cross section. Author concludes that longitudinal or transverse

stiffening results in a "small improvement in efficiency" in comparison with unstiffened plates, but that a "significant increase in efficiency" is achieved by either $0°$-$90°$ or $\pm 45°$ waffle-grid construction. J. W. Clark, USA

5674. Ohasi, Y., and Suzuki, T., Bending of an orthotropic plate clamped on the boundary of a conic section, *J. Aero/Space Sci.* **27,** 5, 386-387 (Readers' Forum), May 1960.

Buckling

(See also Revs. 5619, 5631, 5673, 5718, 5764)

5675. Gerard, G., Handbook of structural stability—Supplement to Part III: Buckling of curved plates and shells, NASA TN D-163, 23 pp., Sept. 1959.

This supplement to part III [AMR **11** (1958), Rev. 1570] reviews recent theoretical and experimental results on buckling of curved shells. Some extensions of Donnell's equation and some new results of nonlinear stability theory and of plastic buckling theory are discussed. Experimental results on buckling of circular cylinders under axial compression combined with internal pressure, under bending, and under external pressure are reviewed and compared with predictions of part III.

F. J. Plantema, Holland

5676. Gerard, G., and Becker, H., Handbook of structural stability, Part VII: Strength of thin-wing construction, NASA TN D-162, 83 pp., Sept. 1959.

First part of paper is concerned with orthotropic plate theory and stability of various forms of orthotropic plates. Some results for elastic buckling of orthotropic plates and isotropic sandwich plates are presented in graphical form. A review of methods of evaluating elastic constants and determining buckling stresses is given; for details reference is made to pertinent literature.

Second part of paper deals with buckling and failure of multiweb beams, and stability of multipost and multipost-stiffened beams in bending. Theoretical and experimental results are reviewed and partly illustrated in a number of graphs. Some comments on minimum-weight design are included.

Final section is devoted to a summary of comparative efficiency studies of compression covers, web systems and multicellular thin-wing box beams. F. J. Plantema, Holland

5677. Yamaki, N., Buckling of a thin annular plate under uniform compression, *Rep. Inst. High Speed Mech., Tohoku Univ.* **10,** 129-147, 1959.

The fundamental equations are first derived by integrating the differential equation for the buckled plate. Using these results, the general stability conditions are obtained for twelve different combinations of the boundary conditions of the edges. The least critical loads are determined in dependence on the ratio of radii as the parameter. It is shown that the assumption of symmetrical buckling leads to exaggerated values for the buckling load. The limiting cases of a solid circular plate as well as an infinite strip are also included. The results are elaborated in tables and plotted. J. Valenta, Czechoslovakia

5678. Nash, W. A., An experimental analysis of the buckling of thin initially imperfect cylindrical shells subject to torsion, *Proc. Soc. Exp. Stress Anal.* **16,** 2, 55-68, 1959.

Tests of twenty-six thin cylindrical shells subject to torsion are described. In all cases the geometries of the specimens are such that failure occurs by elastic buckling. Two analytical treatments seek to explain observed reduction in buckling loads from load value indicated by linear small-deflection theory. Tests corroborate validity of these theories. It was found that for a thin shell with known initial imperfections the two theories bracket the experimentally determined elastic buckling load.

From author's summary by H. Fernandez Long, Argentina

5679. Michael, Maureen E., Buckling of unstiffened shear webs with flanged lightening holes, *J. Roy. Aero. Soc.* **64,** 593, 298-299 (Tech. Notes), May 1960.

A semiempirical formula is presented that appears to fit certain published test results reasonably well for the initial buckling case.

J. F. Besseling, Holland

5680. Yusuff, S., Face wrinkling and core strength in sandwich constructions, *J. Roy. Aero. Soc.* **64,** 591, 164-167, Mar. 1960.

Work is an extension of earlier work by the author [AMR **9**(1956), Rev. 445] for finding face wrinkling stress for symmetrical deflection and cores of small and large thickness. The effect of initial waviness is included here and the irregularities are assumed at critical wavelength. Failure of the core under progressive face deflection is used as criterion. Expressions are found relating the amplitude of initial waviness and failing stress with the strength of the core in tension, compression or shear. A reduction is included for inelastic region. Comparison is made with experimental results and reasonably good agreement is obtained.

J. Van Winssen, Canada

5681. Chu, K.-H., Secondary moments, end rotations, inflection points and elastic buckling loads of truss members (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 17-46, 1959.

Using Manderla's equations author studies the relationships between secondary moments and truss buckling load as well as the variation of such moments and the deformations of members (such as end rotations and inflection points) in statically determinate trusses under increasing load up to the point of buckling. It is assumed that the truss is elastic, the deflections are small, and the members are without end eccentricities. The bulk of the paper is a detailed illustrative example of a simple truss.

R. Schmidt, USA

Vibrations of Solids

(See also Revs. 5544, 5564, 5569, 5573, 5667, 5685, 5702, 5704, 5705, 6040, 6042, 6091)

5682. Bailey, J. J., and Finnie, I., An analytical study of drill-string vibration, *ASME Trans.* **82** B (*J. Engng. Industry*), 2, 122-128, May 1960.

A stepped shaft is used as the model to replace the drill string consisting of drill pipe and collars. Neglecting damping and assuming no driving force, the longitudinal and torsional vibrations (uncoupled) are then considered for the case of idealized boundary conditions. The bottom end is taken to be free for torsional oscillations and fixed for longitudinal motions while the top end is assumed to be connected elastically for both motions.

A trial and error method for finding the natural frequencies is presented along with a graphical method based upon the use of charts. Several numerical examples are presented.

D. Frederick, USA

5683. Finnie, I., and Bailey, J. J., An experimental study of drill-string vibration, *ASME Trans.* **82** B (*J. Engng. Industry*), 2, 129-135, May 1960.

This paper describes equipment which has been developed for the measurements of axial force, torque, and axial and rotational motions at the top of a drill string. Measurements made in two wells with this equipment represent the first time these quantities have been recorded during drilling.

A large number of frequencies of vibration were found in the recordings. Some of these, particularly torsional readings, correlated with predicted natural frequencies, but many did not. Several explanations have been proposed for these "extraneous" frequencies, but no completely satisfactory solution is available. In addition, some interesting interrelations between axial and torsional vibrations were observed.

From authors' summary by D. Frederick, USA

5684. Ripianu, A., Contribution to the study of transverse vibration of strings (in Roumanian), *Studii si Cercetari Matematice, Institut de Matematice* **10,** 2, 435–446, 1959.

General analytical solution in form of infinite series is given for the differential equation of a vibrating string for boundary conditions: one end fixed on the x-axis, the other end moving on the x-axis so that the length of the string is a given function of time. Initial conditions are not restricted. Application is made to the case of length decreasing linearly with time, but the obtained result is not discussed from physical point of view, and no numerical illustration is given. G. V. Tordion, Canada

5685. Makai, E., On the principal frequency of a convex membrane and related problems (in English), *Czech. Math. J.* **9 (84),** 1, 66–70, Mar. 1959.

An upper bound of the principal frequency of a convex membrane is established. Neglecting a factor depending on purely physical quantities it contains only the area and perimeter of the membrane.

From author's summary by N. A. Weil, USA

5686. Hersch, J., and Payne, L. E., Effect of a rectilinear stress on the fundamental frequency of a vibrating membrane (in French), *C. R. Acad. Sci., Paris* **249,** 19, 1855–1857, Nov. 1959.

5687. Leibowitz, R. C., Natural modes and frequencies of vertical vibration of a beam with an attached sprung mass, David W. Taylor Mod. Basin Rep. 1215, 39 pp., Sept. 1958.

Analytical and electrical-analog determinations of the natural frequencies and mode shapes of a ship with 18,674-tons displacement, SS Gopher Mariner, are presented. The results are representative of the vibration characteristics of ships having flexibly mounted machinery, cargo, superstructure, etc.

The natural frequencies of a uniform beam with a lumped spring and mass attached are determined by an analytical simultaneous solution of classical equations. The solution of the same system is determined with an electrical analog circuit. The solution, made on the TMB network analyzer, agrees closely with the analytical solution. Also, an electrical analog circuit for a nonuniform beam with a sprung mass is developed and solved with the TMB network analyzer. The frequencies of the natural modes of this system occurring below the sprung mass natural frequency are less than the corresponding natural frequencies of the beam without a sprung mass. Conversely, the natural frequencies above that of the sprung mass are higher than those in the beam without the sprung mass. Another finding is that the nonuniform beam sprung mass system has two natural frequencies with the same number of nodes and the same mode shape. Experimental measurements on the SS Gopher Mariner are presented that are in agreement with this finding.

Author states that the above vibration problem has recently been successfully coded for solution on UNIVAC.

R. R. Bouche, USA

5688. Barr, A. D. S., Some notes on the resonance of Timoshenko beams and the effects of lateral inertia on flexural vibration (in English), 9th Congrès Intern. Mécan. Appl., Univ. Bruxelles, 1957; **7,** 448–458.

Experimental values for the first and second frequency spectra for a free-free beam of rectangular cross section are compared with analytical values obtained from the Timoshenko equations for the flexural vibration of beams. Good agreement is indicated.

An approximate theory for the modification of the Timoshenko equation to include the effect of lateral inertia is developed. Frequency spectra are obtained experimentally for beams with an H-section and a channel section for which it is asserted the third spectrum of frequencies is due to the lateral motion and is of practical importance for certain cross-section shapes.

M. V. Barton, USA

5689. Buchwald, V. T., Low frequency flexural vibrations in elastic plates, *Quart. J. Mech. Appl. Math.* **12,** 4, 454–463, Nov. 1959.

An approximate method for calculating fairly low frequencies of elastic plates is shown, which is justified in cases for which the classical theory of thin plates leads to large errors.

The fundamental assumption is a parabolical distribution of shear stress and transverse displacement along the thickness of the plate. The solution is obtained through the use of a complex variable.

Results are compared with exact equations for propagation of plane waves and with the approximate Mindlin's solution. Differences are very small for all the three possible modes of vibration, if $bn < \pi c_2$, where $2b$ is thickness of the plate, $n/2\pi$ frequency, c_2 velocity of shear waves.

Derivation of equations is shown rather briefly and refers to existing articles of different authors. Nomenclature is more usual for physics than for engineers.

V. Petrovsky, Czechoslovakia

5690. Yu., Y.-Y., Forced flexural vibrations of sandwich plates in plane strain, AFOSR TN-59-567 (Polyt. Inst. Brooklyn, Dept. Mech. Engng. TN 4), 22 pp., July 1959.

Article is fourth in series presenting author's flexural theory of elastic sandwich plates, first two giving general theory for one-dimensional case and third dealing with free flexural vibrations [See AMR **13**(1960), Revs. 2799 and 2878, also *J. Appl. Mech.* **26,** 3, 415–421, Sept. 1959, and **26,** 4, 679–681, Dec. 1959]. Present article extends study to forced vibration in plane strain. Investigation, entirely analytical, indicates important factors to be shear effect in core, rotatory and translatory inertias of core, translatory inertia of faces, and joint effect of flexural and extensional rigidities of faces. Principal modes of free vibration are assumed known. Author states new theory is needed because importance of some of these factors makes essential the retention of high-order differential equations with respect to space coordinate, so that previous treatments in general become too complicated. Example is worked out for simply supported plate.

C. W. Smith, USA

5691. Kalnins, A., and Naghdi, P. M., Axisymmetric vibrations of shallow elastic spherical shells, *J. Acoust. Soc. Amer.* **32,** 3, 342–347, Mar. 1960.

Analysis is based on complete linearized system of differential equations for shallow shells. An exact solution is presented for this particular case in terms of Bessel functions. Authors show that there is no contribution of axial displacement to longitudinal inertia; however, entire effect of longitudinal inertia may be appreciable. Various edge conditions are considered and numerical results given for an example which shows influence of longitudinal inertia to be as much as 11%.

F. I. Niordson, Denmark

5692. Kolotikhina, Z. V., On the vibration of a cylindrical shell in water and the complex acoustical spectrum of its radiation, *Soviet Phys.-Acoustics* **4,** 4, 344–351, May 1959. (Translation of *Akust. Zh. USSR* **4,** 4, 333–340, Oct.-Dec. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

Author assumes that an infinite cylindrical shell vibrates axisymmetrically and that the longitudinal variations of the radial displacements of the shell are harmonic (obey the sine law). With zero initial conditions he solves the wave equation which is connected through boundary conditions with the equation of the vibratory motion of the shell. The problem admits a separation of variables and the consequent reduction to ordinary differential equations. The remaining half of the paper contains the interpretation of the results, the determination of the frequencies and the amplitudes of acoustic pressure. T. Leser, USA

5693. Buzdugan, G., Present methods for computation of machine foundations (in German), *Rev. Mêcan. Appl.* **4**, 1, 113–130, 1959.

The first part of the paper gives a comparison of two common methods for analysis of vibrations of machine foundations. The author by simple algebraic operations proves that the two different approaches as described in the standard books (e.g. Rausch, E., Barkan, D. D.) yield identical results. The second part deals with the vibrations of a hammer-foundation, this system being replaced for analysis by a simple elastically supported three-mass system. As the procedure outlined is a logical extension of standard methods the suggestion of a "new analysis" seems hardly justified.
A. Slibar, Germany

5694. Franken, P. A., Input impedances of simple cylindrical structures, *J. Acoust. Soc. Amer.* **32**, 4, 473–477, Apr. 1960.

A thin cylindrical shell driven in vacuum below its resonance by a point force may be described by membrane theory. Each nonaxisymmetric modal impedance contains a resistance and a mass of equal magnitude, as in the case of an infinite bar. The impedance decreases with increasing mode number up to a "cut off" mode, and stiffness effects become important for modes above the cutoff mode. The analysis includes finite shells and rings.
From author's summary by M. S. Weinstein, USA

5695. Tajime, T., On the variation of displacement of the structures relative to the ground when period ratio is unity through the whole vibration, *Mem. Fac. Technol., Tokyo Metrop. Univ.* no. 9, 681–689, 1959.

Author considers single-degree-of-freedom systems excited at the base at their natural frequency starting from rest position. The natural frequency and damping factor are changed stepwise during the transient stage. Systems represent the behavior of structures during earthquakes. Various changes in damping factor with natural frequency are considered, occurring during the progressive deterioration of concrete, steel, and wooden structures with either a low or high natural frequency. Author's reasoning is difficult to follow. M. Botman, USA

5696. Mazet, R., Effects of a certain amount of plastic deformation on the vibration of a structure (in French), *C. R. Acad. Sci., Paris* **249**, 14, 1183–1185, Oct. 1959.

5697. Mazet, R., Setting up equations for the free vibration of a structure, taking into account a certain amount of plastic deformation in the same direction as the vibration, (in French), *C. R. Acad. Sci., Paris* **249**, 10, 942–944, Sept. 1959.

Wave Motion and Impact in Solids

(See also Revs. 5610, 5684, 5695, 5747, 5750, 5752, 5899, 5904, 5905, 6089)

Book—5698. De Hoop, A. T., Representation theorems for the displacement in an elastic solid and their application to elastodynamic diffraction theory, 's-Gravenhage, Uitgeverij Excelsior, Feb. 1958, 84 pp.

Author develops a representation similar to Kirchoff's formula for the integration of the inhomogeneous wave equation and applies it to the isotropic theory of elasticity. The representation is applied to the diffraction of elastic waves by a screen of vanishing thickness. The problem of a perfectly rigid half plane, a perfectly weak half plane and the saltus problem is solved for an incident plane SH-wave and an incident plane P-wave respectively. The integral equations are solved by Wiener-Hopf technique. No numerical results are given.

There is an extensive bibliography but little attention is paid to current Russian work, e.g. AMR **12**(1959), Rev. 3221. Reviewer considers this an important work which deserves careful study. E. A. Fox, USA

5699. Roever, W. L., Vining, T. F., and Strick, E., Propagation of elastic wave motion from an impulsive source along a fluid/solid interface, Parts 1, 2, and 3: Experimental pressure response; Theoretical pressure response; The pseudo-Rayleigh wave, *Phil. Trans. Roy. Soc. Lond. (A)* **251**, 1000, 455–523, Sept. 1959.

The first part of report describes the experimental set-up and the precautions taken to ensure no unwanted effects (reflections, etc.) intervene. A pressure wave is generated in the water layer and two solids were used: (a) a high viscosity pitch, and (b) plaster of paris. These were chosen to give a 1 : 1.8 ratio in the velocity of transverse waves. The velocity of compressional waves in the water is intermediate between these two. The second part of the report discusses the theoretical side of the problem. The approach is based on the work of Lamb [*Phil. Trans., Roy. Soc. Lond. (A)* **204**, 1–42, 1904], Lapwood [*Phil. Trans. Roy. Soc. Long. (A)* **242**, 1949] and Cagniard [1939, "Réflexion et Réfraction des Ordes Seismiques," Gauthier-Villars, Paris]. The analysis is intricate and depends on the evaluation of contour integrals, with branch points and poles in the integrand.

The details of the waveform are examined more clearly in Part 3 of the report and the detailed calculations were carried out on an electronic computer, assuming the pressure distribution of the source is a delta function. The agreement between the observed and calculated results is very striking. These are the highlights of this report, which is full of other results which will be useful to workers in this field. J. M. Jackson, Scotland

5700. Teodorescu, P. P., Computation of a periodically loaded elastic halfplane (in German), *Rev. Mêcan. Appl.* **4**, 1, 141–148, 1959.

Author applies general three-dimensional stress function theory, developed by him in a previous paper, to the special case of semi-infinite elastic solid subjected on its surface to normal stresses which have periodic variation, with different periods, in two perpendicular directions. Formulas in double Fourier series form are obtained for interior stresses and displacements. Numerical results are presented for the special case of square-wave-formed pressure of equal period in each direction.
H. J. Plass, USA

5701. Berg, G. V., and DaDeppo, D. A., Dynamic analysis of elasto-plastic structures, *Proc. Amer. Soc. Civ. Engrs.* **86**, EM 2 (*J. Engng. Mech. Div.*), 35–58, Apr. 1960.

Mathematical model analyzed is a multi-story bent. The bent is a rectangular plane framework of members having ideal elasto-plastic moment rotation characteristics. It is loaded by arbitrary lateral dynamic forces supplied at the joints and in the plane of the bent, or by motion of the base. Connections may be either pinned or fully restrained. Structural masses are lumped at the joints. Damping is assumed viscous. Deformations due to axial forces and shear forces are neglected, and the effect of axial forces upon the stiffnesses and plastic hinge moments of the members is neglected.

Using an adaptation of the increment theory of plasticity and a step-by-step numerical solution, the dynamic response is obtained in the plastic range. As plastic hinges occur during the step-by-step analysis, "corrector" solutions in which the frame has hinges at these locations are superimposed on the elastic solution. The method is adapted for computer use.

Paper appears to offer a useful procedure for the dynamic response of frames, using automatic computers. However the validity of the mathematical model apparently has not been verified by experiment. J. N. Siddall, Canada

5702. Baker, W. E., The elastic-plastic response of thin spherical shells to internal blast loading, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 139–144, Mar. 1960.

Title problem is investigated for spherically symmetrical transient loading. The response is obtained from small-deflection theory for shell materials with various degrees of strain-hardening. For large strains, where thickness b and radius a vary with time but are assumed to obey the material incompressibility law $b a^3 = a$ constant, a nonlinear equation for radial displacement is derived; numerical solutions for the response are obtained with a digital computer. There is reasonable agreement between theoretical and experimental values of the maximum strains. However, further work is required to determine the conditions for which the nonlinear theory must be used to predict the response.

G. B. Warburton, Scotland

5703. Hwang, S.-Y., and Davids, N., Graphical analysis of the formation of shock fronts in materials, *J. Mech. Phys. Solids* **8,** 1, 52–65, Jan. 1960.

Impact phenomena in cylindrical bars, having nonlinear stress-strain relation, are investigated by the graphical method. The stress-strain relation, which can be concave down or concave up, is approximated with a two-straight-line relation, resulting in two velocities of propagation, the higher velocity being valid for the large strains, and the lower velocity for the small strains, or vice versa. Some materials, a foam plastic, have a combined stress-strain relation, concave up followed by convex up. The multiple scabbing phenomenon of materials, due to tensile reflection from a free boundary, is analyzed and presented graphically, in a number of examples, namely: (a) Plastic reflection of elastic wave at fixed boundary; (b) formation of shock front by loading beyond the critical stress; (c) elastic-plastic reflection of an elastic pulse from a fixed boundary; (d) reflection of a triangular pulse having an initial discontinuity at a free end; (e) interaction of elastic-plastic contours for a triangular pulse; (f) elasto-plastic contours starting from a strong triangular pulse for a soft-rubberlike material; (g) interaction of elastic-plastic contours by fast elastic overtaking wave; (h) multiple scabbing of materials due to tensile reflection of a compression pulse. Some general conclusions are drawn, such as: (1) When a fast elastic unloading wave overtakes a plastic wave in the same direction, a region of permanent deformation is generated by the interaction of the two waves; (2) assuming that the dynamic stress is relieved at a fracture surface, the methods discussed can be used for determining the scabbing surfaces.

Reference is made to two previous papers: "Multiple scabbing in materials," by Sudhur Kumar and Norman Davids, *J. Franklin Institute* **263,** 4, 295–302, Apr. 1957, which discusses the phenomenon of scabbing; and "Elastic-plastic analysis of scabbing in materials," by Sudhur Kumar and Norman Davids, *J. Franklin Institute,* **265,** 5, 371–383, May 1958, which contains the explanation of the method as used for the present problem

K. J. DeJuhasz, USA

5704. Hastrup, O. F., The effect of shock waves on buildings (in Danish), *Bygnsstat. Medd.* **30,** 1, 1–18, June 1959.

The walls are assumed to be completely restrained by stiff framed floors at which the mass of each storey is concentrated. Thus the structure can be displaced only in a translatory manner. The walls consist of a material which is ideally elastic up to a yield point and then ideally plastic. External forces due to the shock wave are replaced by a concentrated force at the level of each stiff floor. The problem of instability is neglected.

Differential equations of motion for the complex system influenced by a simple external load are transformed into a new set of differential equations for a simple elastic system influenced by a complex external load. The displacements are resolved into its components in the directions of the eigenvectors of the natural modes of vibration and the final equations are solved using the phase plane method. A numerical example is given.

Reviewer believes that a more complete list of references would have been advantageous; e.g., the following papers published in *Bull. Earthquake Res. Inst., Tokyo Imp. Univ.* by Fukutomi, **12,** 3, 1934; Sezawa and Kanai, **14,** 3, 1936; **14,** 2, 1936; **14,** 4, 1936, and others could have been mentioned.

S. T. A. Odman, Sweden

5705. Bycroft, G. N., White noise representation of earthquakes, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 2 (*J. Engng. Mech. Div.*), 1–16, Apr. 1960.

Author postulates "standard large earthquakes" as family of ground motions having constant-velocity or constant-energy expected spectra. Through comparison with true-earthquake maximum responses of linearly damped elastic and elasto-plastic systems with one degree of freedom he shows relatively good approximation in the postulated motions. Analyses were performed by means of an electric analogy to the systems under consideration.

Accuracy of the true-earthquake responses used has been questioned (in written discussions of the paper by G. N. Bycroft, H. J. Murphy, and K. J. Brown, title source, Oct. 1959) but this does not invalidate the comparison. White noise responses differ appreciably from those of actual earthquakes for very small natural periods and, in the case of elasto-plastic systems, also for large natural periods, showing the convenience of using a more refined approximation than strictly flat energy spectra.

E. Rosenblueth, Mexico

Soil Mechanics: Fundamental

(See also Revs. 5600, 5614, 6093, 6118, 6120)

Book—5706. Golushkevich, S. S., The statics of the boundary states of soil masses (in Russian), Moscow, Gostekhizdat, 1957, 288 pp. + illus. 9r 15k; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6745.

This book is the posthumous edition of the original monograph, a task which the author, who died in 1956 was not able to carry out in full. It was to S. S. Golushkevich that credit is due for the working out of the graphical methods for the integration of the equations for the boundary equilibrium of a granular medium ["The plane problem in the theory of boundary equilibrium of a granular medium," L.-M., Gostekhteorizdat, 1948] and the theory of plasticity [S. S. Golushkevich, R. M. Rappoport, *Tr. Leningr. Politekhn. In-ta,* 1950, (21)]. In the monograph now under review there is a substantial developmental account given of these methods and a series of new problems are solved. For the first time discontinuous solutions for the statics of a granular medium are systematically used. In so far as the theorems on the uniqueness of the solution worked out by S. A. Khristianovich [*Mat. Sb.* **1,** no. 4, 1938] and V. V. Sokolovskii ["The theory of plasticity," M.-L., Izd-vo AN SSSR, 1946] refer to statically determinable continuous solutions, the introduction of discontinuous solutions raises the question on this uniqueness. The inadequacy of equations for equilibrium and of boundary conditions and the necessity to introduce the extremal

principle is discussed in paragraph 26, but, as questions relating to kinematic analysis are not touched on in the book, there is no full solution of the problem available here. The editorial staff has supplied editorial notes to the book which supply the reader with references to the latest works on the subject. One of these notes, however (p. 158), requires some small amplification. It is stated that the continuous solutions do not appear to be unique. This assertion, applied to statically determinable problems, is only true in relation to velocities, but where stresses are concerned these, as already mentioned above, are determinable in a unique way.

The book consists of six chapters with the following headings: Chapter I. Investigation of the boundary stressed state of the unit volume of the soil mass. Chapter II. The most simple boundary states of the soil mass. Chapter III. Elementary combined problems in the theory of the boundary equilibrium of the soil mass. Chapter IV. Differential equations for the boundary equilibrium of the soil mass. Chapter V. Integration of the differential equations for the boundary stressed state of the soil mass. Chapter VI. Some problems of the boundary equilibrium of the soil mass.

G. S. Shapiro

Courtesy Referativnyi Zhurnal, USSR

5707. Deresiewicz, H., The half-space under pressure distributed over an elliptical portion of its plane boundary, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 111-119, Mar. 1960.

A solution of the title stress distribution problem is given for a flexible plate and uniformly distributed loading. Formulas for displacements at the surface; approximate solutions for case of small eccentricity and for points in the vicinity of the center respectively; vertical stresses and displacements along the axis are given. Solutions contain elliptic integrals; numerical results have been summarized in tables and curves. There is a rather narrow field for practical applications. A. Kezdi, Hungary

5708. Kezdi, A., Earth pressure on retaining wall tilting about the toe (in English), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **25,** 3-4, 377-392, 1959.

A theory is developed which concludes that there is no movement of the soil along a plane surface passing through the point of rotation of the wall. A plane forming the limit of the deforming wedge of soil intersects the wall at some height, b_o, above the base. The pressure on the wall is a combination of earth pressure at rest up to b_o, and active earth pressure above this point. The conclusions and experimental evidence do not agree with former investigations, such as the theoretical analysis by C. F. Jenkin, C. B. E., LL. D., F. RS, M. Inst. C. E., and the experimental work of Professor Takabeya, briefly described in *Engineering*, May 13, 1932, and more extensively in other publications.

F. J. Converse, USA

5709. Zarkhi, A. Z., Determination of the limiting resistance of a soil to a lateral load (*in Russian*), *Trudi Leningrad In-ta Inzh. Vodn. Transp.* no. 25, 54-59, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6704.

An approximate solution is put forward for the determination of the limit of resistance of the soil to lateral loading. The normal component of passive stress is generally sought in the form of

$$p_{ps} = \gamma y F(\varphi, \varphi_0, \alpha, \varepsilon)$$

where y is the depth from the soil's surface, F the sought function, depending on the angle φ of internal friction, the angle of friction φ_0 of the soil to the wall, the angle of slope α of the back face of the wall to the vertical and the angle of slope ε of the free surface of the soil. The medium is assumed to be ideally granular ($c = 0$). Function F, found by the V. V. Sokolovskii method ["Statics of a granular medium," Moscow, Gostekhizdat, 1954], is analyzed for the values $\varphi_0 = \varphi = 15^\circ$ to 40° and $\varepsilon = 0$; the author then expresses the function by the approximate formula

$$F = \frac{\cos\varphi}{\cos\alpha(1-\sin\varphi)} \exp\left[\left(\varphi + \frac{\pi}{2} \pm 2\alpha\right) \operatorname{tg}\varphi\right] \qquad [1]$$

If there is an evenly distributed load q on the surface of the filled-in area, the limit of resistance of the soil to lateral loading, when taking account of the cohesion of the soil, can be determined by the method of superimposition. In that case we would obtain

$$p_{ps} = F(\gamma y + q\cos\varphi\cos\alpha) + c(F\cos\varphi\cos\alpha - 1) \qquad [2]$$

where F is determined by means of the formula [1]. The approximate solutions obtained are sufficiently simple but require complex calculations and give results close to those of the data obtained by a less approximate theory as well as to the experimental data.

A. I. Govyadinov

Courtesy Referativnyi Zhurnal, USSR

5710. Choudhury, P., On the effect of indentation of sandy soil by a flat-ended cylinder (in English), *J. Sci. Engng. Res., India* **2,** 2, 233-238, July 1958.

The paper's hypothesis is that a sandy soil does not act like an isotropic elastic medium for which

$$(E/\mu) = 2(1+\sigma) \qquad [1]$$

holds but that, due to lower resistance in shear to slipping of soil granules compared to a solid as proposed by Weiskopl in 1945, it acts such that the ratio of elastic modulus in shear μ would be greater, or

$$(E/\mu) > 2(1+\sigma) \qquad [2]$$

where σ is Poisson's ratio.

Using entirely a mathematical approach, expressions are formulated for general stress-strain relations, stress function, and components of displacements. These are specialized for the problem's boundary values leading to relations for stress, pressure, and displacement along the contact surface of the rigid cylinder and the semi-infinite soil. The pressure and displacement relations are compared to those obtained by Sneddon in 1946 for the isotropic case for which Eq. [1] holds.

Reviewer believes that the hypothesis of inequality [2] is interesting and might be of significance in soil mechanics. However, the paper is developed so tersely with essential material such as definitions of many of the symbols omitted that it is difficult to follow. For example, how inequality [2] is introduced in the development is not apparent. Also in the comparison for the one numerical case presented, properties used were those of steel and are not at all representative of a sandy soil. G. J. Tauxe, USA

5711. Scheuch, G., Elasticity of non-saturated clays (in French), *C. R. Acad. Sci., Paris* **249,** 12, 1031-1032, Sept. 1959.

5712. Scheuch, G., Elasticity of non-saturated clays. Loading tests with rigid circular plates (in French), *C. R. Acad. Sci., Paris* **249,** 14, 1194-1195, Oct. 1959.

5713. Man, F. L., Suggestion for improving the method to determine the f value in the rock-pressure theory of Professor M. M. Protodyakonov (in Chinese), *Chinese J. Civil Engng.* **6,** 5, 392-395, May 1959.

Soil Mechanics: Applied

(See Revs. 5645, 5708, 6109, 6115)

Processing of Metals and Other Materials

5714. Ivlev, D. D., Rigid punch indentation into a plastic half-space, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23,** 2, 394–404, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York, 22, N. Y.)

Plasticity equations in spherical coordinates are specialized to give flow parallel to concentric spherical surfaces with characteristic relations analogous to plane flow. Results are used to solve problem of wedge-shaped indenter $r > 0$, $\theta = (\pi/2)$, $|\varphi| < \varphi_0$, on semi-infinite half-space $\theta \geqslant (\pi/2)$ in terms of usual spherical coordinates r, θ, φ. Solution gives indenting pressure identical with Prandtl's plane case. Particular solution for conical wedge flow analogous to Prandtl's wedge solution also given. Finally, problem of rectangular indenter is treated on the basis of what appears to the reviewer to be a specialized plasticity condition. Cylindrical flow normal to the indenter edges is assumed, and again the indenting pressure is identical with that for the plane strain case.

E. H. Lee, USA

5715. Omodaka, S., On the influence of anvil weight and rigidity of supporting material (represented in the form of equivalent spring) on hammer-forging effect, *Bull. JSME* **1,** 4, 342–348, Nov. 1958.

An analysis is given of deformation of test pieces for an infinite anvil, a finite unrestrained anvil and a finite anvil supported on a specified spring. Paper considers lead and steel specimens and adopts a forging force increasing linearly with time for the former and independent of time for the latter. Author concludes that spring constant has only a marginal effect on forging deformation and that for anvil/hammer weight ratios greater than a certain amount (not stated but about 10), this ratio has little effect on deformation. Experiments with model hammers using spring-supported anvils and solid-founded anvils are described and results support the theoretical conclusions. Reviewer believes work to be useful and worthy of further detailed study. In deriving the theory, author assumes that time-load characteristics are the same for an infinite anvil and for a finite one (f in equations 3, 8 and 12). The theoretical conclusions drawn derive partly from this assumption.

J. F. W. Bishop, England

5716. Omodaka, S., On the impact stress in hammer forging, *Bull. JSME* **1,** 4, 348–356, Nov. 1958.

Paper is complementary to preceding review. Experiments are described to determine the load-time characteristic in impact forging. Using a suitable load cell and oscillograph, characteristics are obtained on both a model drop hammer and a steam hammer with both lead and (hot) steel specimens. It is concluded that the forging stress is sensibly time-independent for steel but increases linearly with time for lead. Reviewer believes these conclusions are adequate for a technological investigation into the characteristics of hammers as opposed to properties of materials studies.

J. F. W. Bishop, England

5717. Ota, T., Shindo, A., and Fukuoka, H., An investigation on the theories of orthogonal machining, *Bull. JSME* **2,** 5, 115–123, Feb. 1959.

The authors present another theoretical treatment of the shear-angle problem. The solution uses the plasticity conditions of Hill to relate the shear angle to observed cutting forces for those conditions where a built-up edge is present. The authors proceed to calculate the limits of the shear angle compatible with plasticity theory and thereby question the assumptions of the Lee and Shaffer solution. This paper will be of interest to those who concern themselves with the theory of metal cutting.

L. V. Colwell, USA

5718. Miyagawa, M., Buckling limits of tool dimensions in cupping operation, *Mem. Fac. Technol., Tokyo Metrop. Univ.* no. 9, 618–630, 1959.

Paper gives semiempirical relations for determining the critical dimensions of the drawing-tool for cupping of both shallow recessed shells and deep-drawn shells. Experimental illustrations are given for the cupping operation with spherical punch.

L.-W. Hu, USA

5719. Gideon, D., Simon, R., and Grover, H., Some thermal and physical aspects of cutting, Amer. Soc. Tool and Manufacturing Engrs., Collected Papers, **58,** Book 1, Pap. 76, 7 pp., 1958.

Some theoretical and experimental contributions to metal cutting research are discussed. Particular emphasis was placed on the temperature aspect of the problem.

B. W. Shaffer, USA

5720. Rozenberg, A. M., and Kufarev, G. L., Evaluation of degree of plastic deformation of cut metals (in Russian), *Vestnik Mash.* **38,** 6, 49–52, 1958.

In the process of cutting, circles drawn on the side face of copper samples are transformed into ellipses with equal areas. Before machining, lines on the face are parallel to direction of moving tool, and after, parallel to the front surface of tool. From the length of the semi-axis of ellipses the principal strains are calculated for various rakes of tool. A formula is derived for the shear strain, which describes the results of the experiments better than the formula from Merchant [R. Hill, "Plasticity," Oxford 1950, p. 207].

H. Mussmann, Germany

Fracture (Including Fatigue)

(See also Revs. 5695, 5759, 5760, 5761, 5762, 5768, 6091)

5721. Barenblatt, G. I., On equilibrium cracks formed in brittle fracture, *Soviet Phys.–Doklady* **4,** 4, 802–805, Feb. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **127,** 1, 47–50, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

This brief preliminary article is based on Muskhelishvili theorem that

$$\int_a^b g(x)\ \sqrt{\frac{x-a}{b-x}}\,dx = 0, \qquad \int_a^b g(x)\ \sqrt{\frac{b-x}{x-a}}\,dx = 0$$

where $g(x)$ are the normal tractions on a crack extending from a to b. Compressive tractions, which synthesize the cohesive bonds, are applied over a region at the ends of the crack just sufficient to close the crack at the small end region, then it is shown

$$\int_{-l}^{l} p(x)\ \sqrt{\frac{l-x}{l+x}}\,dx = K\sqrt{2l},$$

where $p(x)$ are the stresses which would be present at the crack in the absence of the crack, $2l$ is the length of the total crack, K is a material constant called the "force of cohesion"; it is similar to the "fracture toughness parameter" of Irwin [*ASTM Bull.* Jan., 1960, pp. 29–40]. When the integral exceeds the right side the crack will propagate.

G. H. Sines, USA

5722. Williams, D., Crack propagation in sheet material—some conclusions deduced from a combination of theory and experiment, Aero. Res. Counc. Lond., Curr. Pap. 467, 29 pp., 1960.

Despite much experimental work, no adequate theory of crack propagation in thin sheet has been developed, so that prediction of the behavior of prototype pressurized structures from tests of models has left something to be desired. Author sets out to establish a method of correlating various tests on flat sheet and

pressurized cylinders by examining existing data. He first finds that sheet thickness has no effect and that, for a given material, if proportionality of crack and specimen dimensions is maintained, the failing stress will always be the same. These propositions are found to be consistent with test results on flat sheet, but do not completely explain scale effects observed in pressurized cylinders. Author examines the bulging of the crack lips which results from the release of the hoop tension by the crack, and shows that the stress distribution at the ends of the crack due to the local pressure load is quite different from that due to the hoop stresses. This effect naturally does not exist in flat sheet tests.

From these considerations, Williams is able to suggest means of predicting the failure of specimens of other dimensions, and to conclude that an empirical constant found by Peters and Kuhn [AMR **11**(1958), Rev. 1601] for the aluminum alloys 7075-T6 and 2024-T3 "is likely to be the same for all structural materials and for all sizes of cylinder."

Reviewer believes this paper is an admirable piece of physical reasoning of a kind engineers see in print too seldom, and that the author has contributed a valuable insight to the problem.

A. D. Topping, USA

5723. Craggs, J. W., On the propagation of a crack in an elastic-brittle material, *J. Mech. Phys. Solids* **8,** 1, 66–75, Jan. 1960.

By analytical methods which are an extension of the Griffith theory, author concludes, for a semi-infinite crack in an infinite medium, that the force required to maintain a steady rate of crack extension is higher for a higher crack extension rate.

J. D. Lubahn, USA

5724. Annaratone, D., Inspection of stability of brittle materials (in Italian), *Ingegnere* **33,** 3, 217–224, Mar. 1959.

The classic failure conditions of Saint-Venant, Guest (Tresca), Beltrami, Huber (Mises) and Mohr are presented. Author considers that for a brittle material some combinations of these conditions must be used.

N. E. Cristescu, Roumania

5725. Stroh, A. N., A simple model of a propagating crack, *J. Mech. Phys. Solids* **8,** 2, 119–122, May 1960.

A model of a crack is developed in which the surface energy in the Griffith treatment is taken to depend on the temperature and strain rate. It is shown that such a crack shows a transition from brittle to ductile behavior as the temperature is raised.

From author's summary

5726. Drozdovskii, B. A., and Fridman, Ya. B., A method of assessing the sensitivity of materials to cracking during impact bending, *Indust. Lab.* **25,** 3, 336–345, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 3, 320–328, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

An increase in the width of the specimen with crack, the change to impact test, and the reduction of temperature facilitate an increase in the sensitivity when testing specimens with cracks for the detection of some brittle states (brittle annealing, annealing brittleness, etc.) of steels. It is recommended that the impact bending test with specimens having a crack of cyclic overload and a cross section similar to the cross section of the Menager specimen should be adopted as the main method for the assessment of sensitivity to cracks. The crack can be obtained by different types of cyclic loading but the use of the resonance vibrator is the most practicable. The main characteristic of the test is the total rupture energy related to the cross-sectional area, it is designated by a_{cr} and expressed in kilogram-meters per square centimeter. It is shown that in a number of cases the impact bending tests on specimens with cracks reveal the brittle state of steel with a greater sensitivity than the testing of standard impact specimens, and in some cases it characterizes the material in a manner fundamentally different from the ordinary impact tests.

From authors' summary

Book—5727. Rassweiler, G. M., and Grube, W. L., editors, Internal stresses and fatigue in metals (Symposium held at General Motors Res. Lab., Detroit and Warren, Mich., 1958), Princeton, N. J., D. Van Nostrand Co., Inc., 1959, x + 451 pp. $11.

Book is collection of papers presented at the Symposium at General Motors Technical Center, September 1958. First 80 pages contain review articles by R. F. Thomson on "Engineering interest in internal stresses," by C. S. Barrett on "Scientific interest in internal stresses," by E. Orowan on "Causes and effects of internal stresses" (chemical effects, thermal volume change, plastic change, microstresses, new interpretations of strain hardening and Bauschinger effect), and by J. D. Eshelby on "Scope and limitation of the continuum approach." (The latter deals with the theory developed by Eshelby, Kondo, Bilby, Kröner, Nye where the customary zero right sides of the compatibility equations are replaced by components S_{ij} of an "incompatibility tensor" which is then interpreted as a continuous distribution of dislocations; see in this connection also Kröner, AMR **12**(1959), Rev. 5911, and paper in *Arch. Rational Mech. Anal.*, 1960, p. 273, as well as article by B. Bilby in "Progress in Solid Mechanics" **I**, 1959.) In the next 122 pages there are papers by A. Guinier, R. E. Marburger and D. P. Koistinen, H. M. Bender, P. B. Hirsch, R. V. Coleman, H. G. F. Wilsdorf, J. Nutting, R. Truell, E. W. Müller and W. T. Pimbley and J. F. Mulson discussing experimental work (x-ray diffraction, electron interference, etching techniques, ultrasonics, electron-microscope, ion-microscope work, etc.) pertaining to the study of crystal lattices, imperfections and stresses. Müller and co-workers present some startling photographs of arrays of atoms and the gaps left in the arrays when some atoms are removed. In the next 174 pages papers by P. Haasen, J. Friedel, E. R. Parker and D. M. Fegredo, T. J. Dolan, M. R. Hempel, R. L. Mattson and J. G. Roberts provide new analytical results for interaction of dislocations with each other and with the surrounding medium, as well as experimental results and interpretations of residual stresses, strain hardening, surface conditions. In the next 88 pages, L. F. Coffin, Jr., N. J. Wadsworth, E. A. Gulbransen and T. P. Copan, R. C. Frank present their results on cyclic straining, effect of surrounding medium, and contained gases. The book concludes with summaries by A. M. Freudenthal and C. S. Smith

G. Horvay, USA

5728. Younger, D. G., Jr., A fatigue hypothesis based upon stabilized unidirectional slip, *Proc. Amer. Soc. Test. Mat.* **58,** 576–595, 1958.

An hypothesis involving considerations of two factors—"unidirectional slip" that ceases early in fatigue life and "alternating slip" that continues throughout fatigue life. The hypothesis is applied to the interpolation and extrapolation of fatigue data from one combination of mean and alternating stress to a different combination. This is illustrated, for data from available literature, on a steel, a magnesium alloy and three aluminum alloys.

H. J. Grover, USA

5729. Frankel, H. E., Bennett, J. A., and Holshouser, W. L., Effect of oleophobic films on metal fatigue, *J. Res., Nat. Bur. Stands.* **64** C (*Engng. Instrumentation*) 2, 147–150, Apr./June 1960.

The fatigue strengths of a low-alloy steel, a magnesium alloy, and a copper-beryllium alloy were increased by coating the specimens with certain polar organic compounds. Also the dispersion of the results was much less for coated specimens of these materials than for clean ones. Similar tests showed no effect with

titanium or 6061 aluminum alloy, and only a slight improvement for 17-7 PH stainless steel.

The full beneficial effect of the coatings was found only with compounds having a carbon chain of at least twelve, and this effect was not significantly reduced when the coated specimens were tested in water. Organic solvents (benzene and xylene) had a deleterious effect on the fatigue life of materials that were improved by oleophobic coatings.

It is suggested that the effect of the coatings is principally due to their ability to present a barrier to water and oxygen molecules.

From authors' summary

5730. Signorelli, R. A., Johnston, J. R., and Waters, W. J., Thermal-stress fatigue cracking of turbine buckets operated at 1700°F in a turbojet engine with long periods of operation between starts, NASA TN D-272, 22 pp., Feb. 1960.

Thermal-stress fatigue resistance of alloys Sel-1, B & B, forged Udimet 500, and Inconel 713 was studied at 1700°F in a J47 engine with an average of 11 hours at rated speed between starts. These data were compared with those of a previous investigation with an average of 1.4 hours of rated-speed operation between starts. The data include the number of starts to cause bucket cracking, the number of starts to crack 50% of the buckets of each alloy group, and the mode and rate of crack progression to cause fracture of buckets. From authors' summary

5731. Kawamoto, M., and Kimura, K., On non-propagating cracks in fatigue of metals, *Bull. JSME* **3,** 9, 41-47, Feb. 1960.

Authors attempt to explain the formation of nonpropagating fatigue cracks, by setting up an algebraic statement of the conditions under which nonpropagating cracks will form. The fatigue strength at any point on a stressed section is taken to increase with distance in from the surface, becoming asymptotic to a maximum value when the distance is appreciable. The proposal postulates the existence of two constants; a fatigue-strength reduction-factor (in the presence of a crack) which is a material constant, and an "inner strengthening coefficient" which is constant for a given material and stress condition. Authors present experimental data from which they calculate values of the second of these constants from values of the first obtained by a method not made clear in the paper. Although the first constant is stated to be a material constant, two different values are used for the same material. The authors' experimental data neither substantiate nor disprove their general proposal.

A. L. Titchener, New Zealand

5732. Endo, K., The effect of atmosphere on fatigue strength of carbon steels at elevated temperatures, *Bull. JSME* **3,** 9, 76-80, Feb. 1960.

Fatigue tests of carbon steels were carried out at 550°C under rotating bending and also under repeated torsion in town gas to reduce air oxidation, as a first step to study the effects of atmosphere on fatigue strengths at elevated temperatures. For long lives under low stresses, the strength was higher in gas than in air, and the influence of corrosion fatigue due to oxidation was found in air at high temperature. Meanwhile the strength was lower in gas than in air for short lives under high stresses, and the *S-N* curves in air and in gas cross each other. This may be attributed to the hydrogen embrittlement resulting from the decomposition of water vapor. The *S-N* curve at elevated temperatures may take a considerably different shape if the effects of oxidation by air are removed, and its slope becomes more gentle after a long time.

From author's summary

5733. Waldron, G. W. J., and Summerton, J. M., Research on strain-ageing, hardening and softening of metals by fatigue (Technical Summary Report, Sept. 1957-Feb. 1959, Contract AF 61 (514)-1180), AFOSR TN 59-774 (Dept. of Industrial Metallurgy, Univ. of Birmingham, England; ASTIA AD 219 717), 120 pp.

This report consists of two parts. The first describes work carried out by G. W. J. Waldron, M.Sc., on the fatigue of aluminum-magnesium alloys. The second deals with the researches of J. M. Summerton, B.Sc., on the fatigue of zinc single crystals. The two projects are clearly differentiated and no attempt has been made to combine the accounts.

Part I. Previous work relating to the fatigue of aluminum-magnesium alloys has been extensively reviewed.

Room temperature fatigue experiments have been conducted to find the condition under which true fatigue limits occur in aluminum-magnesium alloys. In the solution-treated condition, these materials do not have fatigue limits, but in the as-extruded they do. Metallographic observations show that increasing magnesium content reduces the width of slip marks (striations) which occur during fatigue, and the amount of surface cracking is also reduced. Cracks have been observed in aluminum-1% magnesium and aluminum-3% magnesium in as-extruded specimens remaining unfailed below the fatigue limit.

Tensile experiments at −196 C subsequent to fatiguing at −196 C, with intermediate resting at temperatures in the range −80 − + 20 C in aluminum and aluminum-magnesium alloys, have shown hardening and softening effects which it is suggested are due to interactions of vacancies and solute atoms with dislocations.

Preliminary experiments are reported showing the effect of temperature on fatigue life for a given stress in aluminum-3% magnesium. These indicate that there is an increase in fatigue life corresponding to the hardening effects in the fatigue-tensile experiments.

Part II. A technique is outlined for growing large seeded zinc crystals of any desired orientation, and a method of acid machining gage lengths in these crystals is described.

Zinc crystals of five different orientations (X, Chi, between 30° and 60°) have been fatigued to fracture at room temperature in push-pull tests at a frequency of 100 c/s. *S-N* curves have been found for each orientation, and when the curves are re-plotted in terms of resolved shear stress they superimpose, indicating that the fatigue life of a crystal is determined by the shear component of the applied stress. A few crystals have also been fatigued at 50 c/s, and it is shown that failure is dependent on time of testing rather than on the number of cycles.

Fracture of zinc crystals by fatigue usually takes place by cleavage across the basal plane, and this initiates in a direction parallel to the active slip direction.

During fatigue, specimens harden during approximately the first 3×10^4 cycles, and the flow stresses produced are one hundred times that of a virgin crystal. A logarithmic law of recovery has been deduced for fatigue-hardened crystals rested at room temperature.

A method has been developed for measuring hysteresis loops during fatigue, and it has been found that the amount of plastic strain per cycle decreases with increasing number of reversals for the first 10% of life and then remains constant for the remainder.

From authors' summary

5734. Carter, T. L., and Zaretsky, E. V., Rolling-contact fatigue life of a crystallized glass ceramic, NASA TN D-259, 35 pp., Mar. 1960.

The rolling-contact fatigue properties of a crystallized glass ceramic were investigated with the five ball fatigue tester. Fatigue spalls similar to those common in bearing steels were observed at maximum theoretical (Hertz) compressive stresses of 265,000, 295,000, and 300,000 psi. At room temperature, load-carrying capacity was approximately one-fifteenth that of AISI M-1 tool steel. The effects of contact stress, contact angle, test lu-

bricant, and test temperature up to 700 F are reported. This material may be useful in low-load, short-duration applications where an operating temperature above the limits of steels is the paramount design consideration. From authors' summary

5735. Marco, S. M., Starkey, W. L., and Hornung, K. G., A quantitative investigation of the factors which influence the fatigue life of a V-belt, *ASME Trans.* **82** B (*J. Engng. Indust.*), 1, 47–59, Feb. 1960.

A new design method for V-belts has been developed. The new method involves a horse-power-life relationship which has been derived on the basis of the results of a vast experimental program of belt testing involving many hundreds of tests, together with an analysis of these data which introduces several new concepts of stress analysis for rubber-textile structures.

From authors' summary

5736. Sereda, P. J., Atmospheric factors affecting the corrosion of steel, *Indust. Engng. Chem.* **52**, 2, 157–160, Feb. 1960.

Author has measured the rate of corrosion on 4 × 6 × 1/8-in. panels of low-carbon plain steel exposed for eight months at two sites in Ottawa at locations 800 yards apart. One of the sites differed from the other in being close to a power house which led to a much higher sulfur-dioxide pollution rate than at the other site. Time-of-wetness on both skyward and groundward sides of the panels was measured with moisture-sensing elements devised by the author. Temperature of a corroding sample of the steel was measured and the sulfur-dioxide pollution rate was determined by the lead-peroxide deposition method. The weight loss by corrosion was determined at the end of each month. Analysis of the data showed that the logarithm of the corrosion rate, measured in mg/centimeter^2 per day of wetness, was linearly related to the sulfur-dioxide pollution rate, measured in mg of sulfur trioxide per dm^2 per day, and the temperature (monthly average during the time of wetness). The importance of the sulfur-dioxide pollution rate is indicated by the observation that a three-fold increase in pollution rate at 39°F increased the rate of corrosion by a factor of 1.9.

Author points out need for correction to include effect of salt spray if corrosion is to be determined in coastal areas. He suggests that his findings should facilitate the duplication of outdoor conditions in corrosion tests in the laboratory.

W. Ramberg, Italy

5737. Semerchan, A. A., Vereshchagin, L. F., Filler, F. M., and Kuzin, N. N., The theory of the destructive action of cavitation (in Russian), *Inzhenerno-Fizicheskii Zh.* **3**, 3, 87–90, Mar. 1960.

The action of a stream flowing from a nozzle 0.64–0.84 mm in diameter at a rate of 400–600 m/sec in eroding metals is investigated. The effect on erosion of the rate of the stream, distance from the nozzle, angle of incidence of the stream, diameter of the nozzle and "water cushion," is studied. Experiments show that the stream produces considerable destruction in a short time. The effect increased sharply when the stream is divided. The results can serve as a confirmation of the theory of the destructive action of cavitation, based on the multiple renewal of direct blows delivered to the surface of the metal by the liquid.

From authors' summary

Experimental Stress Analysis

(See also Revs. 5750, 5766, 5785, 5786)

5738. Frocht, M. M., and Thomson, R. A., A three-dimensional photoelastic investigation of the stress distribution in an axially thick ring, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 1–10, 1959.

The main purpose of this paper is a discussion of the three-dimensional effects on the stress distribution of a thick ring subjected to two forces of equal magnitude acting oppositely on its outer boundary. The state of stress was determined experimentally by the freezing technique in three-dimensional photoelasticity, using photometric devices. A special feature of the test is that the hole of the ring was rebored after a first freezing cycle to eliminate effects due to great deformations of the model. Extended controls were made to check the obtained results.

W. Schumann, Switzerland

5739. Photo-elastic research of grain materials (in German), *LGM Mededelingen, Laboratorium voor Grondmechanica, Delft* **4**, 4, 119–134, Apr. 1960.

Photoelasticity can be applied to the investigation of stress conditions in granular materials by use of Dantu's method, which produces transparency of the material by filling the pores with a liquid having a matching refraction index. Application of this method in the Laboratory in Delft showed that the principal stress directions become visible in circular polarized light. A filament pattern of bright lines is created which defines the directions of the largest grain stresses. The determination of isoclines with linear polarized light can therefore be omitted. It is doubtful whether quantitative stress analysis can lead to accurate results.

This is demonstrated by test results obtained with a calibration beam compensator and by an approximate analysis of the relation between grain stresses and the intensity of over-all brightness in a dark circular polarized field. From summary

5740. Atsumi, A., Note on stress concentrations in a strip under tension and containing an infinite row of semicircular notches, *Technol. Rep. Tohoku Univ.* **23**, 1, 21–30, 1958.

Normal photoelastic methods are employed to determine peak stresses in 19 shapes of notched strip. Stress-concentration factors are based on net section decrease with decreasing pitch of notches. Results for pitch equal to width of strip show good agreement with calculated values. Stress distributions around edge of some notches are also shown.

Reviewer believes end effect is due to proximity of loading holes. Practical question whether peak stress at end notch is greater than at the middle notch is not dealt with.

H. Fessler, England

5741. Jorgensen, S. M., Overstrain tests on thick-walled cylinders, *ASME Trans.* **82** B (*J. Engng. Industry*), 2, 103–121, May 1960.

The experimental work described covers pressure-expansion tests on thick-walled, closed-end cylinders of four different steels. The tests covered stress levels through the plastic and strain-hardening ranges to destruction, at pressures up to 100,000 psi. A theoretical method is given for computing expansion and bursting strength, based on both tension and torsion data. Finally, a simplified formula for ultimate pressures is described and checked against the experimental data. From author's summary

5742. Bartolozzi, G., Experimental investigation of stresses in the rivets of sheet-stringer flat panels, compressed beyond the critical load (in Italian), *Aerotecnica* **39**, 5, 219–231, Nov. 1959.

Edge compression tests are performed on sheet-stringer flat panels of 24 S-T3 aluminum-alloy, assembled with aluminum-alloy rivets, for the determination of the stresses in the rivets caused by the action of the buckled sheet.

After the analysis of the problem by the Buckingham theorem, the testing technique is established and the criteria for the interpretation of the experimental results are given.

Curves are reported in which values of $\frac{\sigma_t}{E\,\varepsilon_{cr}}$ are plotted against

$\frac{\bar{\varepsilon}_x}{\varepsilon_{cr}}$ (σ_t is the tensile stress in the rivet located nearest the buckle crest, E the modulus of elasticity of the sheet, ε_{cr} the critical deformation and $\bar{\varepsilon}_x$ the mean longitudinal deformation in the stringers). From author's summary

5743. Buzdugan, G., Petre, A., and Blumenfeld, M., Strain gage measurements below water in the interior of a pressure container (in French), *Bul. Inst. Politehnic, Bucuresti* **20**, 1, 195–204, Jan./Mar./1958.

5744. v. Grol, H. J., Hakkeling, B., and Schuerman, J. A., Results of stress and deflection measurements performed on a swept-back box beam and their comparison with theoretical results, Nat. LuchtLab. Amsterdam Rap. TN S. 536, 73 pp., Jan. 1959.

Boxes 12-in. × 6 in. × 60 in. long, fabricated in aluminum about 0.030 in. thick with lengthwise spar booms and stringers and flightwise ribs, formed in plan a V held at apex. Cantilevers were tested by applying vertical displacements with screw jacks, and measuring loads, strains (resistance gages) and vertical deflections. Reviewer infers that beams remained elastic and did not buckle. Results are given for seven loading conditions which are not described in this report. In view of the completeness with which results are reported this is a regrettable omission.

Stresses and deflections are compared with two sets of theoretical values computed for this beam in two different ways by J. P. Benthem [Nat. LuchtLab. Amsterdam, Reports S417 (Nov. 1953) and S436 (June 1954)]. One set of Benthem's values lies closer to the experimental results than the other, of course, but generally both agree well. Only serious departure of theory from test results is in shear stresses near cantilever root; authors successfully correct theory in this region to take account of shear stiffness of spar booms. J. H. Percy, New Zealand

Material Test Techniques

(See also Revs. 5722, 5736, 5797)

5745. Dow, M. B., and Peterson, J. P., Bending and compression tests of pressurized ring-stiffened cylinders, NASA TN D-360, 27 pp., Apr. 1960.

The results of tests on pressurized ring-stiffened cylinders subjected to compression and bending are presented and discussed. The results obtained at high values of internal pressure differ from those obtained by previous investigators in that the theoretical small-deflection compressive buckling coefficient of 0.6 was nearly achieved in each test. Small amounts of internal pressure had a greater stabilizing effect in the bending tests than in the compression tests. From authors' summary

5746. Kammerer, A., On the measuring of the elastic coefficient of materials (in French), *C. R. Acad. Sci., Paris* **249**, 19, 1861-1863, Nov. 1959.

5747. Karpov, G. I., Strain distribution in the compression of cylinders at a high rate of deformation, Pt. 2 (in Russian), *Fiz. Metallov i Metallovedeniye* **2**, 1, 172-175, 1956; *Ref. Zbl Mekh.* no. 8, 1958, Rev. 9334.

Copper crusher tubes were tested in compression at a rate of 100 m/sec, effected by a striker pin struck by a bullet. The masses of the striker and the moving parts of the hammer were so adjusted that the crushers would be compressed to 30–40% of their original length. A curve is given for the distribution of the strains over the height of the cylinder. The strain values were determined from the change in area of the individual cross sections. The distribution of the strain-hardening effect was determined by machining the dynamically deformed sample down to a cylinder of lesser diameter and succeeding stepwise compression of the latter at a low rate of deformation. Flow curves have been plotted, from inspection of which the author concludes that the mechanical properties are inhomogeneous over the height of the sample. In conclusion, the observation, already published in the literature, is confirmed that the strain varies inhomogeneously in height, due to the action of inertia forces and the irregular distribution of the deformation velocities over the height of the cylinder.

P. O. Pashkov
Courtesy Referativnyi Zhurnal, USSR

5748. Abramov, A. D., Plant for fatigue testing of torsion springs, *Indust. Lab.* **25**, 3, 366-368, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25**, 3, 349-350, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5749. Kononenko, V. G., An impact-testing machine for the rapid testing of materials, *Indust. Lab.* **25**, 3, 360-363, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25**, 3, 343-345, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5750. Cunningham, D. M., and Goldsmith, W., Short-time impulses produced by longitudinal impact, *Proc. Soc. Exp. Stress Anal.* **16**, 2, 153-162, 1959.

Accuracy of dynamic sensitivity to very short strain pulses of SR-4-type-A strain gages is verified by sandwiched piezoelectric quartz crystals. Strain gage and quartz crystal gave nearly identical shapes of strain-time plots for pulses as short as five times gage length. Momentum measurements gave excellent check with manufacturer's gage factor in steel bars, but 8% error for aluminum bars. Reviewer believes rise times of order of 10 μsec and pulse durations of order of 20-30 μsec are short enough to warrant confidence in more general use of strain gages in many dynamic applications. D. K. Felbeck, USA

5751. Rastegaev, M. V., and Borisov, A. E., Apparatus for high temperature testing for impact tension of test samples made of heat-resistant alloys (in Russian), *Zavod. Lab.* **24**, 7, p. 871, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 7045.

A description is given of an attachment to a pendulum hammer-type MK-30 which enables tests to be carried out on samples for impact tension at temperatures up to 1200–1300°. The heating took place in "Silitov" furnace immediately prior to the testing.

V. S. Namestnikov
Courtesy Referativnyi Zhurnal, USSR

5752. Shemarin, N. N., Apparatus for oscillographic recording of the forces and deformations manifesting themselves during impact force reactions (in Russian), *Zavod. Lab.* **24**, 10, 1256-1258, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 7104.

A description is given of the apparatus and the measuring instruments employed for testing brittle nonmetallic materials for impact compression. The velocity of the impact mechanism was up to 6m/sec maximum. The measurement of the forces and deformations was carried out on resistance strain gages, while the measurements of velocities were made with induction strain gages. It is proposed to compute the magnitude of the forces with the assistance of a velocity curve. S. A. Shesternikov
Courtesy Referativnyi Zhurnal, USSR

5753. Slavina, N. P., Conversion tables for hardness numbers, *Measurement Techniques* no. 6, 645-648, Mar. 1960. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 6, 27-29, Nov./Dec. 1958 by Instrument Society of America, Pittsburgh 22, Pa.)

Tables show relative hardness for Rockwell, Brinell and Vickers methods as derived from tests on a range of carbon and alloy steels, each tempered to three different hardnesses. Vickers values were used as comparison standard. Table for mean devi-

ation of results on a series from average curve is of interest. For any individual value the effect of scatter must also be considered. Checked against conversion tables used in this country appreciable differences are found. Author concludes that hardness conversion tables can be only approximate, even when restricted to specific ranges of metals and alloys. Reviewer agrees.

E. B. Shand, USA

5754. Lisitsyn, V. D., On the relationship between macro and microhardness of metals, *Indust. Lab.* **24,** 4, 528-531, June 1959. (Translation of *Zavod. Lab. USSR* **24,** 4, 467-469, Apr. 1958 by Instrument Soc. Amer., Pittsburgh 22, Pa.)

Author shows by some experimental examples of his own and by plotting already published results from Russian and foreign colleagues that the exponential law of Kick (1890) and Meyer (1908) for the relation between micro- and macrohardness numbers is valid for most of the reported test result numbers. The Meyer exponent n used in the analogical expression $P = ad^n$ is found to be just exactly 2 with some relatively insignificant, numerical scatter. In the graphs, however, it appears that at very low loads within the conventional microhardness range the relationship breaks down. Reviewer thinks this may be due to the rather trivial fact that the use of very low loads for a pyramid indenter will exaggerate inaccuracies such as the unavoidable edge effects of the indenter.

R. Nilson, Sweden

5755. Bodyako, M. N., Loiko, Yu. M., and Pavlyukevich, B. L. Investigation of changes in hardness of a heated deformed metal, the heating medium being a high frequency current (in Russian), *Sb. Nauchn. Trudf Fiz.-Tekhn. In-ta Akad. Nauk BSSR* no. 4, 170-180, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6990.

The investigation deals with the influence of the principal parameters of an induction heating unit and the degree of deformation on the hardness of Armco iron mark E and of steel mark 1 × 18N9T after annealing. Induction heating was carried out in a high-frequency unit type MGZ-102 (111 kv, 2500 Herz). The hardness of the steel 1 × 18N9T was measured by the Brinell test and the hardness of the Armco iron by the Rockwell test (scale B). It was shown that the curves for the change in hardness in relation to the degree of deformation reach their maximum with a degree of deformation varying from 5 to 30%. With increase in temperature this maximum is not expressed as clearly and shows a tendency to shift to the side of the smaller deformations. When the temperature of heating is raised the hardness decreases, showing bigger decreases for larger degrees of deformation. With increase in the velocity of heating the hardness increases, and this influence is more pronounced at low temperatures and for steel mark 1 × 18N9T. The relationships of changes of hardness to temperature and the speed of heating in the case of steel mark 1 × 18N9T are steady, while in the case of Armco iron they show discontinuity at a heating temperature somewhat exceeding the temperature of phasal conversions. It was established that in induction furnace annealing the hardness is a little greater than in the furnace process.

G. A. Tulyakov

Courtesy Referativnyi Zhurnal, USSR

5756. Kanamaru, K., Ikari, K., Kishimoto, T., and Fukada, E., Non-destructive quality test of adhesive joints by means of resonance measurements (in English), *Kolloid Z.* **170,** 2, 123-131, June 1960.

The dynamic elastic modulus E' and the loss factor tan δ of adhesive joints have been measured at an ultrasonic frequency of 50 kc/s by means of a coupled resonant bar method and the results of these resonance properties have been considered in their relation to those of the thickness b and the strength F of the joints.

From the results it was found that E' as well as tan δ are so intimately correlated with the bond strength F that a single $E' - F$ or tan $\delta - F$ correlation curve, typical of the adherend material, is obtained, independently of the type of adhesive and of the condition of adhesion employed, so long as comparison is made of the resonance properties and F at a fixed joint thickness b for each of adherends used.

The results indicate the possibility that the resonant method for determining the resonance properties of an adhesive joint can be used as a nondestructive quality test of the joint.

The results obtained as regards $E' - F$ and $E'(F) - b$ relationships, and the effect upon them of adding some fillers have been qualitatively considered, taking into account the residual stresses and their distribution in the adhesive joint.

From authors' summary

5757. Sofronov, Yu. D., Determination of the Young modulus of elasticity by the electrical method, *Indust. Lab.* **25,** 4, 489-491, Apr. 1960. (Translation of *Zavod. Lab., USSR* **25,** 4, 472-473, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The measured specimen is fastened in a special electrical device and, by changing the length of the free portion of the specimen, moment at which the resonance appears is obtained. It is determined according to the maximum oscillation amplitude of the specimen. By measuring, at this moment, the length of the free part of the specimen, it is possible to calculate the elastic constants E and G determining the dependence between the geometric dimensions, material of the specimen and the frequency of its oscillations.

From author's summary

5758. Deutsch, V., A new ultrasonic tester for boiler and chemical apparatus (in German), *ZVDI* **102,** 12, 457-458, Apr. 1960.

Ultrasonic inspection is assuming increasing importance among the methods of nondestructive materials testing. Of late a very handy instrument has been built that lends itself in particular to the testing of boilers and chemical apparatus. X-ray inspection can be effectively supplemented by ultrasonics.

From author's summary

5759. Shevandin, E. M., Assessment of the tendency of steel to brittleness in service. Evaluation of the effect of the scale factor, *Indust. Lab.* **24,** 8, 1134-1142, Sept. 1959. (Translation of *Zavod. Lab., USSR* **24,** 8, 1017-1024, Aug. 1958 by Instrument Society of America, Pittsburgh, Pa.)

The effect of scale upon cold brittleness, with special reference to use of structural steel in buildings, was studied. Tests were made with different steels, different heat treatments, different plate thicknesses, and different orientations of specimen to plate surface. Effect of scale with and without geometrical similarity was studied. It is shown that data obtained from tests described can be used to formulate safety criteria with respect to cold brittleness.

R. J. Roark, USA

5760. Vladimirskii, T. A., Criterion of steel brittleness, *Indust. Lab.* **24,** 8, 1142-1147, Sept. 1959. (Translation of *Zavod. Lab., USSR* **24,** 8, 1024-1028, Aug. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Paper reports tests intended to ascertain if same critical temperature of brittleness is indicated by impact strength and by granularity of fracture. Conclusion is that the two criteria are not in agreement, and that probable reason is fact that they reflect processes taking place at different stages of deformation and fracture.

R. J. Roark, USA

5761. Gladshtein, L. I., and Prokof'ev, V. I., Experiments on the rupture of shaped samples when under deflection in the plane of least stiffness (in Russian), Material used in steel constructions (Materialyi po Stal'n. Konstruktsiyam), **2,** Moscow, 1958, 220-238; Ref. Zh. Mekh. no. 6, 1959, Rev. 6952.

Models of welded joints made from steel type MST-3 were subjected to repeatedly varying deflection through an angle of 6°. An

assertion is made regarding the possibility of fracture of the samples when bent two or three times through a small angle. When testing the samples of rimmed and killed steel of normal quality two types of rupture were observed: viscous and brittle. The deduction was drawn that the appearance of viscous rupture is connected with irregular peak accumulations of plastic deformations in the vicinity of the geometrical concentrates of stresses; in such a case the rupture starts when the limiting magnitude of the sum total of plastic deformation is reached in that danger zone. It is established that brittle rupture of the sample only starts at negative temperatures and on impact loading. In contrast to viscous rupture, in which the crack invariably makes its appearance in the metal of the sample, brittle fracture is characterized by a much more frequent production of cracks in the metal connecting the welded seam. Recommendations are made for ensuring the reliability of the samples.

G. A. Tulyakov
Courtesy Referativnyi Zhurnal, USSR

5762. Drozdovskii, B. A., Palkin, B. A., and Ryazanov, N. V., Resonance vibrator for producing cracks in test specimens, *Indust. Lab.* **25,** 3, 358-359, Apr. 1960. (Translation of *Zavod. Lab., USSR* **25,** 3, 341-342, Mar. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Properties of Engineering Materials

(See Revs. 5549, 5614, 5617, 5627, 5665, 5721, 5722, 5724, 5727, 5728, 5729, 5732, 5734, 5736, 5747, 5753, 5754, 5755, 5768, 5774, 5794)

Structures: Simple

(See also Revs. 5552, 5606, 5611, 5641, 5643, 5679, 5681, 5695, 5696, 5701, 5705, 5744, 5796)

Book—5763. Merritt, F. S., (editor), Building construction handbook, New York, McGraw-Hill Book Co., 1958, xxxi + 859 pp. + index. $15.

A review of a book written two years after publication, hence, additional years after the various chapters had been written—as is the case with this review—may cover different aspects than are found in a review prepared immediately after publication. This is especially true today when progress in building construction is so rapid that revised editions must be on the mind of the publisher while the printing of the first edition is underway. The first, 1958, edition of the Building Construction Handbook, written by outstanding specialists in the various fields covered and edited by a well-known senior editor of *Engineering News-Record*, falls in the above category of books. A second edition which is brought up-to-date can already be visualized by the reviewer.

A multitude of fundamental facts as well as well-established basic information of the most practical nature make this handbook a valuable source of know how, especially for the neophyte student of building and its related aspects. The statement about agreements executed on Sunday, in the chapter on professional services and business practices, can be as vital as that concerning the placement of joists with edge knots, in the chapter on wood construction. Such statements are likely to remain valid indefinitely. On the other hand, the paragraph on cut nails, in the chapter on builders' hardware, was correct only prior to the time when the U.S. production of cut nails had dwindled from more than eight million kegs to less than one-half million kegs, while that of wire nails increased from one-half million kegs to almost eighteen million kegs. In an up-to-date revised edition, the original statement that cut nails "are generally used for fastening flooring" might read, "cut nails previously used universally for fastening flooring are being replaced more and more by helically threaded flooring nails in the installation of flooring, a requirement found in F.H.A.'s Minimum Property Standards of November, 1958."

In the chapter on building materials, basic materials and their variations, such as the widely introduced gypsumboard and its foil-covered variety, are presented only briefly. Fortunately, this and similar building materials are described in more detail in a special chapter on lath and plaster, farther back in the handbook. No doubt some of the materials, such as glass, are covered too briefly; while others, especially those described by Professor Dietz, are covered in such detail in a minimum of space that the respective chapters fulfil the true purpose of the handbook and provide a maximum amount of accurate factual data.

The chapters on stresses in structures and soil mechanics and foundations may be considered basic texts which cover more ground than was taught to most practitioners in the building construction field. The sections on concrete, structural steel, and light-weight steel construction present in 188 pages so much information that they are doubtlessly used as texts in many classes.

In the well-presented chapter on wood construction, more details on fire-retarding treatment could have been included, particularly since reference is made to the combustibility of timber structures. In the eight pages on floor coverings, the paragraph on wood flooring could have been elaborated, since no mention is made of plank flooring, plywood and cross-laminated flooring, parquetry, prefinished wood flooring, treated wood flooring, etc. In the chapter on roof coverings, references to glass-fiber asphalt shingles would be added today. A listing of advantages and limitations of roofs consisting of painted insulation-board panels, which have found acceptance for farm buildings, would have been in order.

Special subject matters, such as acoustics, water permeability of masonry structures, and thermal insulation round out the picture prior to the 120 pages devoted to heating and air conditioning, water supply and purification, plumbing and sprinkler systems, waste-water disposal, electric power and lighting. These items are followed by a chapter covering the important aspects of vertical transportation.

Reviewer missed the coverage of light wood framing in the chapter on walls and partitions. Fastening in building construction should, in the reviewer's opinion, have been given more detailed consideration, because a building can only be as good as its fastenings. Thus, fastening of siding, sub-flooring, underlayment, flooring, etc., are of such importance that they should have been covered in the handbook.

One may argue with respect to chapter arrangement. The chapter on windows is separated from that on doors by one on walls and partitions. Part of the chapter on lath and plaster could have been a part of the chapter on building materials where lath and plaster are discussed, and the remainder could have been included in the chapter on walls and partitions. The introductory chapter on professional services and business practices would have been logically followed by the chapters on management, insurance and bonds, specifications, cost estimates, and surveying.

On the whole, this handbook on building construction provides a wealth of valuable information with which builders and architects should be fully familiar. If, in the foregoing statement, emphasis is given to the omission of certain subject matters in the handbook, this is done with the thought that a second edition could be enlarged to provide such information as is missed by the reader.

E. G. Stern, USA

Book—5764. Gornov, V. N., Strength and stability of concrete constructions (in Russian), Moscow, Gosstroiizdat, 1957, 120 pp. + illus. 5r 45k

Results are published of the author's work on investigations of the strength of deflecting and eccentrically compressed lightly re-

inforced and pure concrete construction components. Studies were made of a light concrete with a volumetric weight of 1.6 to 1.75 t/m^3 mixed with "Kashirsk" slag and of a heavy concrete with a volumetric weight of 2.1 to 2.5 t/m^3 mixed with granite chips. The mean relative extensibility of the concrete for momentary deflection tests on 75 beams was 1.8×10^{-4}; the limiting compression of the slag concrete for momentary axial compression on 24 prisms was 15×10^{-4}. Because of the creep in the concrete the limit of deflection on 28 concrete beams, under loads for a duration of 114 24-hour periods continuously, proved to be approximately twice as large for the heavy concrete and three times as large for the slag concrete as the deflections for momentary loads. Observations over four months disclosed a relative shrinkage growth in slag concrete reaching a magnitude of 4×10^{-4}.

Formulas are given for the determination of the carrying capacity of compressed concrete components, the formulas being based on the assumption that the limiting state is characterized by the appearance of the first power cracks in the danger section of the component, which takes into account the initial eccentricity in the application of the load and the limiting extensibility of the concrete. A formula is also furnished for the determination of the curvature of the deflecting component of the concrete when consideration is being given to the effect of prolonged loading. A comparison of the calculation formulas derived by the author with the formulas embodied in the existing building standards and rules of SN and P shows that the SN and P formulas give lower values for the breakdown load while the author's formulas agree well with the experimental data. The creep in concrete reduces the carrying capacity of columns, which justifies to some extent the provisions of the SN and P formulas.

On p. 64 the author gives expression to rather indefinite ideas regarding "assumed" and "initial" eccentricity. In Fig. 27 the graph for the limiting deflection moments of a flexible rod is incorrectly shown.

V. V. Pinadzhyan

Courtesy Referativnyi Zhurnal, USSR

5765. Hruban, K., Limit stress of longitudinal reinforcement of reinforced concrete beams (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **26,** 1/2, 29–43, 1959.

Test-results obtained from investigating 66 reinforced-concrete beams can be summarized as follows:

(*a*) The limit stress of a longitudinal reinforcement consisting of round-steel bars, or Roxor-steel bars—the influence of shrinkage excluded—was about 10% higher than the lower yield point of the steel-bars.

(*b*) This statement is also valid in the case of a stronger reinforcement, as long as the percentage of steel does not exceed the standard limit, but under that condition the shearing reinforcement and anchorage of steel has to be adequate.

(*c*) The difference between the two above-mentioned stresses may be explained on the basis of the statistic theory on strength of construction materials, and its calculation is possible under certain conditions. According to this theory, the difference should disappear if the steel is an ideal homogeneous material.

(*d*) Dispersions appearing in the course of tests on the load-carrying capacity of reinforced-concrete beams are to a great extent a consequence of the inhomogeneity of the applied reinforcement.

From author's summary

5766. Bares, R., Transverse action of precast beam structures and their design (in Czechoslovakian), *Stavebnicky Casopis* **7,** 2, 89–106, 1959.

Two experiments on precast concrete floor slabs are described, in which transverse strength is determined. Results agree with Guyon-Massonet approximate theory describing the transverse stiffness of multi-beam slabs [Y. Guyon, *Ann. Ponts Chauss. France* 1946, pp. 553–612, and Ch. Massonet, *Ann. Trav. Publ. Belg.*, 1954, nos. 3, 5, 6].

A. Sawczuk, Poland

5767. Gyengo, T., New method for the determination of the strength of concrete (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **26,** 1/2, 103–114, 1959.

The tensile strength of concrete can be determined generally by two methods. In the first one, test specimens are subjected to pure tension and in the second, unreinforced concrete beams are subjected to bending and tensile strength is deduced from their bending strength. None of these methods is satisfactory and the trouble is that for the determination of tensile and compressive strength, specimens differently shaped and manufactured under different conditions are used. In consequence the two kinds of strengths cannot be considered as related values, characterizing the concrete.

The testing method proposed by Akazawa eliminates the imperfections of the present practice. Tensile strength is determined by applying diametrically opposed compressive loads to a concrete cylinder. Such a loading produces nearly a uniform tension on the section in the plane of loading. Rupture always occurs in the plane of loading when the tensile strength is exceeded. A vertical cylinder of the same dimensions can be used for the determination of the compressive strength. An unambiguous relation exists between the tensile and the compressive strength of concrete determined in this way. Experiments abroad and in the Hungarian Institute for Building Research proved this new testing method to be correct. It would be advantageous to standardize the test cylinders internationally for the uniform determination of the tensile and the compressive strength of concrete.

From author's summary

5768. Granholm, H., General theory for the calculation of reinforced concrete with special regard to the properties of the reinforcement at fracture (in Scandinavian), *Trans. Chalmers Univ. Technol.* no. 209, 228 pp., 1959.

Starting with a description of the more recent results in testing of concrete beams and columns, the behavior of concrete in compression is discussed. Formulas for the failure moment, etc., are deduced using an idealized constant compression zone. The stress and the depth of the compression zone are found by demanding that the calculation shall give moments, etc., identical to the results when using the actual compression and strain in concrete.

The results given by this method are compared with those from a number of tests. The agreement is fairly good.

Further on the treatise contains some very interesting reflections on the factor of safety. Factors include variation in concrete and steel quality, probable increase in loads in the future and type of loads.

The last part of the book gives simple formulas for dimensioning of concrete beams, etc.

A. B. B. Selberg, Norway

5769. Vetryuk, I. M., An experimental investigation on the strength and stiffness of thin-walled ferro-concrete wall panels with ribs on one side (in Russian), *Sb. Nauchn. Rabot In-ta Str-va i Arkhitekt. Akad. Nauk BSSR* no. 1, 3–22, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6872.

A determination is made of the carrying capacity of a panel, natural size, which included the weights of the wall, the coverings, the partitions, the roof and the load at the time of the determination. The moment of appearance of the first cracks was recorded and the character of the disruption of the panel. Graphs were drawn of the stresses in the ribs and the plate in various horizontal sections of the panel. Recommendations are put forward for rational types of sections and reinforcement for the plate and ribs of the panel for buildings of average height (4–6 stories) and the procedure to be adopted for the calculations for the panel.

M. M. Manukyan

Courtesy Referativnyi Zhurnal, USSR

5770. Lessig, N. N., Theoretical and experimental investigations of ferro-concrete beams subjected simultaneously to the action of deflecting and torsional forces (in Russian), Theory of the calculations and construction of ferro-concrete structures (*Teoriya Rascheta i Konstruir. Zhelezobeton. Konstruktsii*), Moscow, Gosstroiizdat, 1958, 73–84; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6878.

The experiments carried out made it possible to indicate possible ways in which breakdown could occur in ferro-concrete beams of rectangular section, working under deflection and torsion and to derive calculation formulas for the determination of the carrying capacity of such beams. From author's summary

Courtesy Referativnyi Zhurnal, USSR

5771. Medvedev, S. N., Calculations for prefabricated prestressed monolithic ferro-concrete constructions subjected to a shearing force (in Russian), *Sb. Trudi Voronezhsk. Inzh.-Stroit. In-ta* no. 4, 39–46, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6880.

Fourteen prefabricated monolithic beams of double T and rectangular section were tested, the beams being taken to be hinge-supported, loaded by two forces along thirds of the span. The magnitude of the principal tension forces did not determine the actual moment of the appearance of transverse cracks, while the calculation with the permissible stresses led to an error of 2 to 2.5 times. It is shown that for constructions of the described type a calculation for the shearing force Q on transverse sections can be utilized. Calculations by the formulas of the TsNIIPS give satisfactory agreement with the experimental data; the divergence lies within the limits of from −12 to +31.7%. The formula for Q is applicable for the calculation of prefabricated monolithic prestressed beams of rectangular section. When making calculations for sections with a flange in the compression zone it is essential to take into account the influence of the flange.

G. A. Tulyakov

Courtesy Referativnyi Zhurnal, USSR

5772. Khmel'nitskii, L. Ya., Ivanov, P. S., and Bondarev, V. A., An analysis of static schemes for the use of prefabricated ferro-concrete pit prop structures (in Russian), Investigations on mine constructions, Moscow, Ugletekhizdat, 1958, 83–96; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6894.

This is an investigation on the selection of rational static schemes of mine-prop structures to withstand rock pressure while taking into account the elastic resistance of the rock stratum. Graphs are drawn of the forces in question for pit props of trapezoidal, polygonal and circular outlines. A comparison of the different forms showed that the most rational was the assembly of polygonal outline and of braced construction for the pit prop, with hinges at the joints which enable the prop to "adapt itself" to the action of the rock pressure. N. K. Snitko

Courtesy Referativnyi Zhurnal, USSR

5773. Ulitskii, I. I., A stressed state in sections of ferro-concrete elements produced as the result of the shrinkage of the concrete (in Ukrainian), Vestn. Akad. Str-va i Arkhitekt. URSR no. 2, 26–30, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6900.

Author's data show that because of the influence of the shrinkage of the concrete the stresses in the reinforcement in tension may increase by more than three times. The tensioning stresses in the concrete produced by the external prolonged loading may decrease by more than twice; the compressing stresses—by 20 to 50%. The increase with time of the modulus of elastic deformation of the concrete exercises an insignificant influence on the change of the stressed state. From author's summary

Courtesy Referativnyi Zhurnal, USSR

5774. Birkeland, H. W., Differential shrinkage in composite beams, *J. Amer. Concr. Inst.* **31,** 11, 1123–1136, May 1960.

Due to normal aging and curing processes, shrinkage occurs in a slab when it is cast onto precast prestressed beams. This shrinkage induces stress into the composite beam and slab construction causing the beams to deflect. An analytical method is presented for predicting the sag. Equations are given for stresses on slab and beam section, shear and moment at the interface, and slope and deflection. This is followed by comparison of computed values obtained from full-size test beams. Values are in close agreement. From author's summary

5775. Brzezinski, K., The analysis of symmetrical single-bay multiple-story frames, *Concrete Constr. Engng.* **55,** 4, 147–153, Apr. 1960.

5776. Harrison, H. B., The preparation of charts for the plastic design of mild steel portal frames, *Instn. Engrs., Australia,* CE **2** (*Civ. Engng. Trans.*) 1, 25–32, Mar. 1960.

The plastic analysis of single-bay pitched roof frames of mild steel, subjected to distributed vertical and horizontal loadings, has been carried out in a manner suited to automatic digital computation. The requirements of the S.A.A. Interim Code 350 with regard to wind loading have been satisfied, and the analysis has been carried out on the basis of the simple plastic theory as applied to pinned and fixed based steel frames of uniform section throughout. The general nature of the programming of such problems for solution using a computer is shown in the form of flow diagrams.

The information so obtained has been assembled as a series of charts which can facilitate the design of a wide range of forms of this type of building. From author's summary

5777. Harder, N. A., Analysis of frameworks (in Danish), *Bygnsstat. Medd.* **30,** 1, 19–34, June 1959.

A method is described for the analysis of frameworks which is especially useful when a number of specific load conditions, including different combinations of horizontal earth pressures, the influence of temperature variations and shrinkage, as well as different combinations of relative settlements of supports are to be investigated.

The method is briefly as follows: Use an auxiliary system where the joints are restrained against both translation and rotation. Determine the moments in the real system subjected successively to unity load in the negative direction of a restraining force or a restraining moment. Thereby the problem of solving for an arbitrary load or deformation condition is reduced to treatment in the auxiliary system in connection with a subsequent superposition of moments from the above-mentioned unity load cases. In the treatment of unity load cases the already worked-out cases are utilized by using the superposition principle. The method may be characterized as an extension of the general principle used in connection with the Cross method for the calculation of systems involving side sway.

The last section of the paper deals with the application of model laws in analysis of frameworks.

From author's summary

5778. Lee, S. L., and Patel, P. C., Bar-chain method for analyzing truss deformation, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 5 (*J. Struct. Div.*), 69–83, May 1960.

An attempt is made to extend the application of the bar-chain method in the analysis of statically determinate and indeterminate trusses. The relationships between the angles of inclination and the unit strains of the members to the actual rotations of the members, and the equivalent end rotations are established. The application of the method is illustrated by means of numerical examples.

From authors' summary

5779. Williamson, R. A., Performance and design of special purpose blast resistant structures, *J. Amer. Concr. Inst.* **31,** 11, 1171–1190, May 1960.

The structures housing scientific equipment used in nuclear tests in the South Pacific are discussed from the standpoint of service experience and structural design approach. Two structures, one sited below ground and the other above ground, are described, and damage history is briefly discussed. The general procedure currently used in the design of these structures is presented and illustrated with a numerical example.

From author's summary

5780. Gregory, M., The use of complementary energy in structural analysis, *Instn. Engrs., Australia*, CE **2** (*Civ. Engng. Trans.*) 1, 9–13, Mar. 1960.

Energy methods are considered as a means of writing down compatibility equations, and the wide applicability of complementary energy is described. It has not generally been realized that complementary energy can be applied to redundant braced frameworks in order to define the behavior of compression members as they buckle, or tension members as they yield. Though the principles outlined are valid for all structures, the argument is restricted to general types of framed structures.

From author's summary by E. R. Johnston, USA

5781. Filho, F. V., Limit analysis of multicell boxes submitted to pure torque, *J. Aero/Space Sci.* **27,** 3, 236–237 (Readers' Forum), Mar. 1960.

5782. Greenspon, J. E., An approximation to the deflections and strains in a uniformly loaded, clamped, rectangular panel subjected to very large plastic deformations, *J. Aero/Space Sci.* **27,** 5, 392–393 (Readers' Forum), May 1960.

5783. Oravas, G.-A., Deformation of ring girders stiffening thin shells of rotation (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 257–272, 1959.

An attempt is made to analyze axisymmetrically stressed ring girders without the common assumption of a large radius/width ratio. The two basic components of deformation, rotation and radial displacement, are treated independently of each other and superimposed in the analysis to achieve the final configuration of the composite structure. It is assumed that only circumferential strains are produced by the rotation. Plane-stress assumptions are used while considering radial displacements.

Ring girders with rectangular and trapezoidal cross sections are investigated in detail and formulas are given for their immediate application in thin-shell analysis. An illustrative example is presented for a ring girder acting as an edge stiffener for a small central opening of a spherical shell with variable thickness.

No defense of the method is presented.

R. Schmidt, USA

5784. Szechy, K., More economical shaping and more exact calculation of abutments (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **26,** 1/2, 191–227, 1959.

Structures: Composite

(See also Revs. 5632, 5664, 5667, 5668, 5669, 5766, 5783, 6040, 6041, 6042, 6061, 6064, 6091)

5785. Konishi, I., Komatsu, S., and Fukumoto, Y., Theoretical and experimental researches on continuous box girder bridges (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 133–146, 1959.

Using torsion-bending theory, paper deals with analysis of three-dimensional stress distribution of continuous box girder bridge. Warping of cross section is emphasized under eccentric loadings. Experimental data were obtained on small plastic model using electric resistance strain gages.

Authors conclude the following:

1. The three-dimensional stress distributions of the continuous box girder bridges under the eccentric loadings can be obtained theoretically by using torsion-bending theory;

2. The external load on the bridge may be distributed on the two box girders of the continuous box girder bridges less sufficiently than on the simple box girder bridges;

3. The spanwise normal stress distribution on the steel deck varies continuously along the whole cross section of the bridge, and these tendencies essentially differ from those of stress analyses as the grillage of beams; and

4. These results are also proved by the plastic model tests.

K. H. Lenzen, USA

5786. Little, G., and Rowe, R. E., The effects of edge-stiffening and eccentric transverse prestress in bridges (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **19,** 169–200, 1959.

A method of calculating the effects of edge-stiffening beams on bridge structures is presented which is used in conjunction with the normal load distribution theories. The theoretical analysis is given in detail elsewhere so only the governing equations for the various effects are given.

The method presented is only applicable where the effective depth of the bridge is constant between the stiffening beams. Where the effective stiffness is considerably reduced at the footpaths or the structural connection between the parapet beams and the roadway is poor, the modifying effects of the parapet beams will be much less than those given in the paper and can be ignored.

A full analysis of a slab bridge with edge-stiffening beams is made and the results obtained from tests on a Perspex model of the bridge are compared with those derived theoretically. A similar analysis is made for a beam and slab bridge where the torsional parameter, α, of the unstiffened bridge is less than unity. The results are again compared with values found experimentally.

The degree of accuracy to be expected from the theoretical analysis and the percentage changes in the longitudinal and transverse bending moments due to the effects of edge-stiffening beams are estimated. Part of the analysis for the above problem is applied to the effect of eccentric transverse prestress in bridges. This application of the analysis is illustrated.

From authors' summary by K. H. Lenzen, USA

5787. Sami, S., Continuous girder bridge with variable moment of inertia, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 1 (*J. Struct. Div.*), 19–39, Jan. 1960.

The purpose of this presentation is to develop and illustrate a simplified procedure for the analysis of symmetrical two-, three-, and four-span continuous girder bridges with variable moment of inertia. It is believed that the method is so simple and rapid in application that a designer will be able to study a sufficient number of combinations of dimensions for a bridge to assure himself that the dimensions finally chosen are economical as well as structurally adequate. The method developed consists of substituting values related to the bridge dimensions, proportions and loadings, into formulas giving the magnitudes of the redundants without the necessity of a sign convention. All constants, coefficients, and functions are made dimensionless so that any consistent system of dimensions may be used. The method is sufficiently simple to be carried out by any civil engineer.

From author's summary

5788. Szidarovszky, J., Approximate determination of subsidiary stresses in transverse truss, due to longitudinal deformation in girders of bridge main beams (in Hungarian), *Mélyépítestudományi Szemle* **10,** 3, 126–130, Mar. 1960.

5789. Coldham, V., Programming for electronic computation of stresses in piping systems, *J. Mech. Engng. Sci.* **1,** 2, 93–102, Sept. 1959.

The techniques used in evaluating the thermal stresses in complex piping systems are outlined. A flow chart for the programming of the flexibility matrix and subsequent solution of the equations is given. The individual steps are all outlined and the merits of the procedure discussed. A specific problem is presented and the results as obtained from the DEUCE computer are shown. An important part of the paper is formed by the appendix which outlines a method for very large systems. The general expressions for anchor loads and internal loads are first developed. The structure is then divided into subsystems which can be solved individually and are later interconnected. The full internal loading distribution is then obtained. An example of this method is included.

J. Van Winssen, Canada

5790. Ghosh Hazra, S. K., Design of piping systems for high pressure and high temperature, *J. Instn. Engrs., India* **40,** 6 (part 2, *Mech. Electr. and Gen. Engng.*), 219–230, Feb. 1960.

The construction of high pressure and high temperature boilers and turbines for modern thermal power stations and industrial plants has made the design and manufacture of steam piping more complex and a highly specialized subject in engineering. Technological advances and research work in laboratories on the behavior of piping structures at extreme service conditions have paved the way in accelerating a high degree of sound and effective piping design.... Research concerning steel for power plant applications is unceasing owing to the fact that thermal efficiency is directly related to temperature of operation. In this connection, in the U.K., work was started some years ago to provide a high-strength steel for steam-plant operation at 1300°F. This paper briefly outlines some fundamental aspects of economical design considerations relating to stresses, reactions and deflections in the piping system in space, including solutions for three-anchored problem. For detailed derivations of flexibility formulas for single- and multi-plane piping systems with two points anchored, reference may be made to the paper "Flexibility analysis of piping structure" by the author in the same *Journal*, **40,** no. 3, pt. 1, Nov. 1959. From author's summary

5791. Dow, N. F., edited by, Important research problems in advanced flight structures design—1960, NASA TN D-518, 49 pp., June 1960.

Research problems related to advanced flight structures are reviewed to define areas of needed emphasis. These areas include: (1) studies of characteristics of planetary and space environments as they relate to structural design; (2) investigations of methods of control of the environmental hazards; (3) evaluations and developments of advanced structural configurations; (4) improvements in methods of structural analysis; and (5) studies of materials selection and development. From author's summary

5792. Grzedzielski, A. L. M., Organization of a large computation scheme in aircraft stress analysis, Nat. Res. Counc., Canada, LR-257, 46 pp., July 1959.

Theoretical and organizational aspects of a large-scale numerical stress analysis covering effects of applied loads and uneven temperature are discussed, using the example of a swept multi-spar model box for which experimental data are available. A large-scale computation, actually performed during the design of a prototype aircraft, is described. From author's summary

Machine Elements and Machine Design

(See Revs. 5549, 5561, 5619, 5634, 5653, 5654, 5659, 5693, 5718)

Fastening and Joining Methods

(See also Revs. 5756, 5763)

5793. Ujiie, A., Various welding problems in the fabrication of high pressure boiler, *Bull. JSME* **2,** 8, 594–601, Nov. 1959.

The different problems are discussed under five headings: materials, welding machines, inspection, heat treatment and root pass welding.

Both low alloy and austenitic steels for steam piping and superheaters are considered. Special attention is given the welding of austenitic material—Ti- and Cb-stabilized. The recommendations for welding austenitic steels are only valid for small-sized tubes, while so far in Japan ferritic material has been used for larger-sized pipes. Author summarizes different types of welding machines currently available, and used for the fabrication of a modern boiler. The inspection of welded joints with different kinds of nondestructive testing methods is discussed. Recommendations for the heat treatment of welds in heavy wall, 2.25 Cr/1 Mo steel pipes are given. Author has compared different technics for root-pass-welding of tubes without the use of backing rings.

B. Lofblad, Sweden

5794. Nikolaev, G. A., and Olshanskii, N. A., Use of ultrasound in welding (in Russian), *Vestnik Mash.* **39,** 4, 51–55, Apr. 1959.

Two aspects of this subject are dealt with: (1) Joining by ultrasonic vibrations and (2) effect of ultrasonic vibrations on residual stresses, deformation, grain size and mechanical properties of welded joints and/or seams.

Results of experiments carried out at the Moscow Higher Technical School (College) and the Moscow Institute for Energetics are briefly described. Experiments covered joints obtained by point, or stitch, and seam method of ultrasonic joining on thin strips of stainless steel, aluminum and several combinations of different metals. Some numerical data are given for stainless-steel joints under shear and tensile stress. Joining of plastics was also subject of experiments and the results appear to be promising for considerably thicker components than in the case of metals.

Second part of article deals with possible effects of ultrasonics on the structure of metal in fusion and resistance welded seams. Experiments, it is stated, tend to show an acceleration of transformation of residual austenite with ensuing greater stability and decrease of deformation. In the case of welded aluminum joints a marked improvement as regards porosity and a certain decrease in grain size was obtained.

Article may be of interest to research workers. Practicing engineers will find little of "real meat" because of lack of numerical data. J. J. Dee, England

5795. Jones, J. B., and Potthoff, W. C., Ultrasonic welding techniques, Amer. Soc. Tool and Manufacturing Engrs., Collected Papers, **58,** Book 1, Pap. 152, 8 pp., 1958.

Article describes equipment, special tooling, weld strength properties, and applications of ultrasonic spot and seam welding. Range of ultrasonic welding has been increased by development of new, improved transducer-coupling systems with capacities up to 8000 watts and with designs to handle special geometric shapes.

F. J. Winsor, USA

5796. Nemeti, L., Elastic-plastic state of tube-joints with prestressed hot socket (in Russian), *Rev. Mêcan. Appl. Bucharest* **4,** 1, 131–140, 1959.

The aim of the paper is to derive computation formulas for prestressed tube joints in the elastic-plastic range. Using formulas for the tube under inner and outer pressure, based on a deformation theory, which is justified in this instance, nomograms are drawn which permit quick calculations in elastic as well as in elastic-plastic range. D. Radenkovic, Yugoslavia

Rheology

(See also Revs. 5546, 5626)

5797. Segawa, W., Maxwell's formula for three-dimensional and large deformation, *J. Phys. Soc. Japan* **15**, 2, 339-344, Feb. 1960.

This paper breaks new ground. The rheological equation for the Maxwell-body written by Maxwell himself for the one-dimensional case assuming linear stress-strain and linear stress-strain-rate relations is further generalized by formulating it for the three-dimensional case, tensorial nonlinearity [following Reiner (AMR **2** (1949), Rev. 547)], and finite strain. It is specialized for the Green and Almansi measures in the strained and unstrained state. Author remarks that different expressions of the generalized Maxwell equation would result from assuming other measures of finite strain, but reviewer thinks that this is taken care of by the second-order tensor terms.

Application is made for the case of simple elongation. Author uses an expression for the strain-rate tensor which the reviewer would have liked to see more elaborated.

M. Reiner, Israel

5798. Longstreth, M. O., and Alfrey, T., Jr., Uniform two-way orientation of plastic films: Part 1, The kinematics of uniform two-way stretching; Part 2, Mechanical development, *ASME Trans.* **82** B (*J. Engng. Industry*), 2, 167-172, May 1960.

In order for a plastic film to be stretched at equal rates in the longitudinal and the transverse direction a highly specific geometrical flow pattern must be established in the stretching zone. This flow pattern involves diverging radial flow lines; the velocity at any point is directly proportional to the distance from the convergences point of the flow lines. These geometrical facts lead to certain design requirements for a machine to be used in the production of plastic film with uniform two-way orientation. In order for new concepts to be expressed in terms of practical working designs for machinery, mechanical development is required. The reduction to practice of the foregoing concept is shown by illustrations.

From authors' summary

Hydraulics

(See also Revs. 5594, 5737, 5896, 6097, 6108, 6130)

Book—5799. Bliznyak, E. V., and Yufin, A. P., edited by, Hydraulic structures and dynamics of river beds [Gidravlika sooruzhenii i dinamika rechnykh rusel], Moskva, Izdatel'stvo Akademii Nauk SSSR, 1959, 242 pp. 13 r. (Paperbound)

This is a collection of 18 papers from the discussion of the river engineering section of the U.S.S.R. Academy of Science for the years 1956-1957. Problems covered include installations of navigation locks, hydraulic transport of solids in pipes, solid transport in rivers and on scale models with associated experimental problems. The river dynamics include problems of flow under conditions of widening and narrowing, meanders and silting; also scale-model investigation of these problems.

The references to literature show that Soviet scientists and engineers are well documented and aware of Western, particularly American, work.

A. G. Foster, England

5800. Escande, L., and Sananes, F., Similarity of waste weirs with an aspiration slit (in French), *C. R. Acad. Sci., Paris* **249**, 19, 1839-1841, Nov. 1959.

5801. Buniatyan, B. L., A steady regime in a pipe conduit after its bursting (in Serbian), *Izv. Akad. Nauk SSSR, Ser. Tekh. Nauk* **11**, 2, 15-22, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6325.

Correlations are derived on the basis of D. Bernoulli's equation, enabling determinations to be made for the characteristics of the motion in a pipe conduit after its bursting. The assumptions are made that the point of bursting is known, also the coefficient of resistance connected with the division of the flow at the point of bursting. The latter was determined by the author by means of special experiments.

V. V. Smyslov

Courtesy Referativyi Zhurnal, USSR

5802. Filippov, G. V., Some experimental investigations on the effect of starting up (in Russian), *Trudi Kuibysbevsk. Aviats. In-ta* no. 5, 56-61, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6317.

Results are given for the experimental investigations of the influence of the inlet portion on the resistance of pipe conduits. The experiments were carried out on a steel tube with a diameter $d = 21$ mm and a length of $l = 6135$ mm with Reynolds numbers of from 30,000 to 70,000. For the resistance of a short pipe in the case of a completely turbulent boundary layer in the inlet portion the author recommends the formula

$$\frac{\lambda_0}{\lambda} = 1 + 4.7\,\frac{d}{l}$$

where λ is the coefficient of hydraulic friction in the case of a stabilized motion, while λ_0 is the coefficient of hydraulic friction of the pipe including the inlet portion. In the investigation of the resistance of a short pipe in the case of a mixed boundary layer in the inlet portion the relation λ_0/λ with $R > R_{cr}$ drops sharply to start with, attains a minimum with $R \approx 5000$, and then increases up to a value given by the above formula.

A. S. Al'tshul'

Courtesy Referativyi Zhurnal, USSR

5803. Guyot, Marie-Therese, Nougaro, J., and Thirriot, C., Numerical calculation of flow in open channels with changing discharge (in French), *C. R. Acad. Sci., Paris* **249**, 19, 1858-1860, Nov. 1959.

5804. Hayashi, T., and Nougaro, J., On the conformity of nonpermanent flow in open channels (in French), *C. R. Acad. Sci., Paris* **249**, 12, 1028-1030, Sept. 1959.

5805. Shinohara, K., and Tsubaki, T., On the characteristics of sand waves formed upon the beds of open channels and rivers, *Rep. Res. Inst. Appl. Mech., Kyushu Univ.* **7**, 25, 15-45, 1959.

Authors present valuable measurements of sand-wave characteristics from field as well as laboratory observations. The data analyses and interpretations derived from this experimental study must be considered tentative.

An attempt was made to predict bed-load motion by using Einstein's [*Proc. Amer. Soc. Civ. Engrs.* **77**, Pap. 78, 1951] concept of roughness to obtain an effective tractive force which is then related to a resistance coefficient. The resulting equation is of the Dubuye type and requires the determination of critical tractive force.

Authors present observations of sand-wave steepness and sand-wave height, for different mixtures. For the fine sand (0.21 mm) the results are somewhat different from the results obtained from many other investigations, including those of Laursen [*Proc. Amer. Soc. Civ. Engrs.* **84**, HY 1, Feb. 1958; AMR **11** (1958), Rev. 4083] and Simons and Richardson [*Proc. Amer. Soc. Civ. Engrs.* **86**, HY 5, 73-100, May 1960]. A relationship between the rate of bed-load transport and mean velocity of movement of sand waves is given by a defining equation stemming from the conservation of sand during equilibrium transport and is similar to that given by Bagnold ["Physics of blown sand and desert dunes," 265 pp., 1941] for desert dunes. Several manifestations of the authors' findings are applied to natural rivers.

L. M. Brush, Jr., USA

5806. Maslen, S. H., On fully developed channel flows: some solutions and limitations, and effects of compressibility, variable properties, and body forces, NASA TR R-34, 22 pp., 1959.

See AMR **13**(1960) Rev. 1267.

5807. Escande, L., Claria, J., and Longerinas, C., Amplitude of the oscillations in waterpower-plant, with a conduit section narrowed to the limit section of Thoma (in French), *C. R. Acad. Sci., Paris* **249,** 13, 1069–1070, Sept. 1959.

5808. Bonnefille, R., The part played by the National Hydraulic Laboratory in investigating the effect of the earth's rotation on tidal phenomena by means of scale models (in French), *Houille Blanche* **14,** 5, 560–567, Aug. 1959.

A brief account of wave experiments in rotating and nonrotating basins. The rotating basins (length of order 1 meter) were: (1) two rectangular basins of uniform depth joined together (geometrically approximately similar to the English Channel), (2) an isosceles right-angled triangle with depth varying linearly from the vertex (approximately similar to the Gulf of St. Malo). Experiments were made with and without bottom friction.

F. Ursell, England

5809. Valembois, J., and Bonnefille, R., Investigation of the effect of the Coriolis force on the propagation of tides as a function of the size of the region under consideration (in French), *Houille Blanche* **14,** 5, 568–585, Aug. 1959.

Wave experiments in a rotating basin are described. The planform is an isosceles right-angled triangle (shorter sides of length 150 cm), the depth varies linearly from 0 at the vertex to 11 cm at the hypotenuse. A wavemaker is placed along the hypotenuse. Diagrams are presented for 4 wave periods, and for speeds of rotation corresponding to latitudes 0, 49°N, 90°N, with and without roughness. (A change in period on the model scale corresponds to a change in the size of the region on the full scale). The diagrams show lines of equal tidal amplitude, cotidal lines, and velocity of tidal currents, and other characteristics. This is a thorough study, which aims at an explanation of the tides in the Gulf of St. Malo.

F. Ursell, England

5810. Lieberman, D., Radiation-induced cavitation, *Physics of Fluids* **2,** 4, 466–468, July/Aug. 1959.

Degassed pentane and acetone were subjected to high amplitude acoustic pressures in a glass-walled spherical resonator. While positron sources had no effect at acoustic amplitudes up to 22 bars, neutron sources were found to result in cavitation (within 15 seconds) at amplitudes of 3.5 and 6.5 bars for the pentane and acetone, respectively. Experiments are relevant to problems of radiation sensitivity of liquids, the theory of bubble chambers, and cavitation. Theoretical considerations presented imply that nucleating agents are recoil carbon ions in pentane and possible oxygen nuclei in acetone. Estimates of thresholds from Seitz's [AMR **11**(1958), Rev. 4577] theory, with and without viscosity effect, are found to bracket the experimental results.

A direct statement of the acoustic frequencies used in missing, although these are defined by the size of the resonator and the statement that the 5th to 7th radial modes were used.

J. M. Robertson, USA

5811. Belkin, H. H., MacLeod, A. A., Monrad, C. C., and Rothfus, R. R., Turbulent liquid flow down vertical walls, *AIChE J.* **5,** 2, 245–248, June 1959.

Free flow of water at room temperature within the Reynolds number range between 200 and 30,000 was investigated by photographic method. Thickness of liquid layers on vertical rod was measured within the stipulated conditions and correlated with findings of earlier researchers. An intense turbulence was most distinct at Reynolds numbers between 16,000 and 30,000.

Agreement with Nusselt's equation for liquid-layer thickness was established, thus formulating added evidence for the predictability of such properties with a sufficient accuracy, by treating the fluid as one in viscous motion between two flat plates. These relationships are expressed in graphic form.

Although limited to room temperature condition, this investigation (and especially the experimental photographic method) is a stimulating contribution for new ideas in such areas of liquids processing where a predictability of liquid-layer thickness and associated turbulence regions at high Reynolds numbers are desirable.

C. R. Bell, USA

5812. Salamatov, Dzh., Flow of liquid from an infinitely long axially symmetric container, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23,** 2, 508–519, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

The jet from a truncated conical container is calculated approximately from a linear integral equation in the boundary velocity. The latter is assumed to be k/r^2 for $z < z_1$ (conical flow), and constant and parallel (a circular jet) for $z < z_2$. The linear integral equation is applied to the interval $z_1 < z < z_2$, the free boundary being determined by iteration. Elliptic integral formulas simplify the numerical work. For a 90° cone, a discharge coefficient of 0.75 is found. It would be interesting to treat the same problem by the method of P. Garabedian [*Pacific J. Math.* **6,** 611–84, 1956].

G. Birkhoff, USA

5813. Zainullin, Z. F., A two-parameter inviscid Gromek flow in a channel of rectangular section bent around the periphery's arc (in Russian), *Trudi Kazansk. Khim.-Tekhnol. In-ta* no. 19/20, 55–68, 1955; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1419.

The problem set is to give a mathematical description of a two-parameter inviscid, homogeneous, spiral flow in the simplest case of a curved channel. In the solving of the problem author follows in its entirety the method used by A. Ya. Milovich [The basis of the dynamics of liquids (hydrodynamics), Gosenergoizdat, 1933], who investigated the special case of the analogous problem for a prismatic rectangular channel. In Milovich's solution, the longitudinal velocity in the contour of the transverse section is equal to zero. By integration of Gromek's equation by the method of natural functions

$$\frac{\partial^2 v}{\partial z^2} + \frac{\partial^2 v}{\partial R^2} + \frac{1}{R}\frac{\partial v}{\partial R} - \frac{1}{R^2}v + \lambda^2 v = 0 \qquad (8)$$

where $\lambda = 2\omega/V$ = constant, the author investigates only mathematically that special case where the boundary conditions determine the natural values in such a way that the longitudinal velocity v on the contour of the section, as is the case with Milovich, is found to be equal to zero, that is to say that the boundary condition when the homogeneous equation is integrated is also homogeneous. Thus it is evident that in the paper an investigation is only made of the pure homogeneous problem, corresponding to one of the simplest special forms for the flow. Here the parameter λ, characterizing the amount of stress in the special motion, can not be given an assigned value and is determined by the dimensions of the longitudinal section and by the number for "the circulation ring" which, taken by itself, has little correspondence with the nature of the phenomenon. One of the characteristic special features of the solution obtained, true also of the Milovich solution, is the sharply irregular distribution of the longitudinal velocities along the section, which does not tally with the numerous experimental data. Another peculiar feature of similar solutions is the appearance, contrary to concepts on the subject, of a "hard" linkage between the flow's discharge and its transverse circulation. The solution obtained may be examined as featuring that boundary case of a homogeneous spiral motion of an inviscid liquid in a bent rectangular bed where, at an assigned discharge, the intensity of the circulation reaches such a high value that a u-distribution of the longitu-

dinal velocities on the section leads to a diminution of the velocity next to the wall to a zero value (the irregularity of distribution of the longitudinal velocities in the circulation flows grows with the intensification of the circulation). The general solution of the problem examined in this paper, with the addition of the assumption that the longitudinal velocity next to the wall is not equal to zero, was worked out later by reviewer. [Bases of the mechanics of spiral and circulating flows, Moscow-Leningrad, Gosenergoizdat, 1958.] O. F. Vasil'ev

Courtesy Referativnyi Zhurnal, USSR

5814. Dmitriev, Yu. A., Investigation of the spreading of a flow started by hydraulic currents in a water basin delimited both as regards width and depth, with the view of using this flow for timer floating (in Russian), *Sb. Trudi Povolzhsk. Lesotekhn. In-ta* no. 52, 75–82, 1957/58; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6302.

Results are published of an investigation into the work done by a hydraulic cross beam of conical form placed in a submerged position. The subsequent investigations of the fields of velocities were carried out in a wide water basin of rectangular section. A periodic wandering was noted in the plane of the disturbed currents of the flow, reaching from one edge of the water basin to the other when the prismatic current was located coaxially with the current-forming cross beam. The connection is noted between the velocity of flow of the current and the period of time taken for the transition of the current from one edge to the other. The author lays particular stress on the surface hydraulic processes. Graphs are furnished to show the relation of the surface axial velocities of the basic portion of the disturbed current of the flow to the distance from the outlet opening of the cross beam to the section of the basic portion being investigated. The author introduces an empirical relation to describe the change of the axial surface velocities of the disturbed current of the flow in its basic portion.

B. I. Komzin

Courtesy Referativnyi Zhurnal, USSR

5815. Nikitin, I. K., Investigation of the structure of turbulent flow in the canals of an irrigation network (in Russian), *Trudi Sredneaz. Nauk-i. In-ta Irrigatsii* no. 91, 55–76, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6338.

Author describes methods used for measuring the structure of the flow in irrigation channels, carried out in 1953 in the hydroengineering laboratories of the SANIIRI (The mid-Asian scientific research institute for irrigation) and the field observations made in the canals of the irrigation systems of the Kirghiz S.S.R and the Kara-Kalfaksk A.S.S.R. Determinations were made of the geometrical dimensions of the cross section, the longitudinal grades, the distirbution by individual verticals of the longitudinal velocities averaged by time and of the vertical pulsation velocities comprised in the transverse circulation velocities, and also of the test samples of the suspended and bottom sediments and of the longitudinal microcontour of the bottom. For the profile of velocities along the vertical the author recommends the relation

$$\frac{u}{v} = \frac{m+1}{m}\left(\frac{y}{H}\right)^{1/m} \qquad \left(m = \frac{0.578}{\sqrt{\lambda}}\right)$$

where u is the velocity at a distance y from the bottom of the canal, v is the mean velocity, H is the depth of the canal, λ is the coefficient of hydraulic friction. In this way the distribution of velocities in the turbulent flow within the relation given to the region of the flow (the region of smooth friction, the transitional region, the quadratic) is determined solely by the magnitude of the coefficient of hydraulic friction. The experiments carried out point to the existence of a one-sign connection between the vertical component of the mean-quadratic pulsational velocity and the indicator of degree of the power principle in the distribution of the velocities. For this linkage the following relation is proposed

$$\sigma\,(\%) = 3.65 + (15/m),$$

where σ is the mean value by depth of the vertical component of the mean-quadratic relative pulsation velocity, expressed as a percentage of the mean velocity v. In this way it is possible to make an appraisal of the magnitude of the turbulence of the flow (when the flow is even and steady) on the basis of experimental hydrometric measurements of the distribution of the velocities by depth, without recourse to supplementary measurements of σ, entailing the use of special apparatus. The investigations made are also evidence of the fact that the presence in the flow of suspended fine sand changes the graphs for the distribution of velocities and increases the turbulence of the flow. A. D. Al'tshul'

Courtesy Referativnyi Zhurnal, USSR

5816. Raspopin, G. A., The evaluation of the change of virtual viscosity when making calculations for stream beds of raised roughness (in Russian), *Izv. Sibirsk. Otd. Akad. Nauk SSSR* no. 1, 108–116, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6339.

A formula is proposed for the determination of Chezy's coefficient for stream beds of a high degree of roughness. The author finds a formula of his own, based on the arbitrary assumption of the possibility of presenting turbulent motion in the form of two items, one of which is proportional to the square of the velocity of friction, and the second to the square of the mean velocity. The formula obtained contains the logarithm of the relative roughness and differs from the ordinary forms because of the multiplier in this logarithm. The constants entering the formula were determined by the author from analysis of the experiments of the New Siberian engineer-construction institute by measurement of resistances in tanks with roughness, the last being simulated by means of transverse bars of rectangular or trapezoidal section. Comparison of the formula with the results of other published works showed satisfactory agreement. E. M. Minskii

Courtesy Referativnyi Zhurnal, USSR

5817. Bol'shakov, V. A., Evaluation of the gradient of a channel during a hydraulic jump (in Russian), *Sb. Nauchn. Trudi Tomskii Inzh.-Stroit. In-ta* **3,** 143–148, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6342.

In the equation expressing the principle of the quantity of motion for a complete jump in channels of rectangular section, consideration is given to the magnitude of the projection of the forces of the volumetric weight of the liquid, enclosed between the sections. The author obtains an equation of the third degree for the determination of the relationship of the combined depths, by assuming first, that at small values for the slope angle of the bottom of the flow $\sin\varphi = tg\,\varphi = i$ and second, that the area of the jump (in a vertical longitudinal plane) can be accepted approximately as the area of the trapezium for the length of the jump, determinable by N. N. Pavlovskii's formula. From the example given and the recalculations it follows that with increase of the slope, the other conditions being equal, there are increases in the values of the second joint depth. The percentage of divergence between the values for this depth, determined by the usual formula (without taking into account the slope of the channel) and those obtained by the author's equation was 4.5% with $i = 0.01$ and 24% with $i = 0.07$. The limiting value for the magnitude of the slope up to which the proposed equation is applicable is not indicated. V. V. Fandeev

Courtesy Referativnyi Zhurnal, USSR

5818. Ter-Abramyants, G. A., The hydraulic scouring of the head works of irrigation systems and of the settling tanks (in Russian), *Trudi Vses. N.-i In-ta Gidrotekhn. i Melior.* **28,** 123–170, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6345.

A description is given of the souring of the head sections of large canals with water-intakes from the rivers Ann-Dar', Syr-Dar', and Vakhsha. The methods used for the calculations of these

scouring operations are furnished. Derivations are given for the equation of the dynamics for the saturation of the flow when the sediment is being scoured, based on a number of assumptions: the plane problem is investigated, the uniformity of the sediment is taken for granted, as also the identical mean hydraulic particle size of the sediment and so forth. Analyses are carried out of previously proposed methods for the determination of the sediment-transporting capacity of the flow. Results are published of laboratory investigations on the scouring of sediment, carried out with sand (diameter of 0.25 mm for the mean particle size) in a tank measuring 0.24 m in width and with a length for the working part of 15 m. The consumption of scouring water varied from 11.75 to 28 l/sec, the mean velocity from 0.35 to 1.10 m/sec at depths of 0.085 to 0.235 m.

V. V. Fandeev

Courtesy Referativnyi Zhurnal, USSR

5819. Kvardakov, A. F., On a hydraulic method of determining the delivery of water in artificial channels (in Russian), *Trudi Omskogo S.-Kh. In-ta* **26,** 163–169, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6351.

It is possible to obtain a formula for the delivery of the water through the morphometric and hydraulic characteristics of sections dividing the upper and lower waters into portions of finite length, This is done by expressing in end differences the differential equation, applicable to the primary portions of the upper and lower waters, for the unsteady motion of the liquid in the open channel and solving this equation relative to the delivery. In the paper being reviewed the proposal is made to utilize the formula obtained in this fashion for the calculation of the delivery in place of the usually adopted means at hydrometric stations of determining the delivery on the basis of measuring the velocities of flow in a transverse section. In order to carry out calculations by the proposed formula, measurements have to be made of thedepth of the flow in the terminal portions and the characteristic of roughness has to be available. The latter can be obtained by means of measurements specially carried out for the purpose. In the author's opinion his proposed (for artificial channels) method is more simple than the method based on the measurements of velocities; its accuracy by comparison with the usual methods is estimated by the author as diverging from them within the limits of ±10%.

V. A. Arkhangel'skii

Courtesy Referativnyi Zhurnal, USSR

Incompressible Flow

(See also Revs. 5545, 5559, 5806, 5854, 5870, 5872, 5890, 5908, 5918, 5927, 6012, 6017, 6028, 6038, 6092, 6097, 6102, 6126, 6133)

5820. Donaldson, C. duP., and Sullivan, R. D., Behavior of solutions of the Navier-Stokes equations for a complete class of three-dimensional viscous vortices, Proc. Heat Transf. Fluid Mech. Inst., Stanford, Calif., June 15-17, 1960; Stanford Univ., 1960, 16-30.

Descriptive account of a solution by the authors of the full Navier-Stokes equations (details to be published soon) for incompressible flow inside a rotating circular cylinder with either uniform injection inward or uniform suction outward. With cylindrical coordinates r, ϕ, z the solutions considered are of the type $u = u(r)$, $v = v(r)$, $w = z\bar{w}(r)$. For this flow the pressure gradient is equal to Cz, where C is a constant.

The solutions for this model can be divided into four families of three-dimensional vortex motions, each of which is described in the paper. An interesting result is the existence of vortex motion with more than one "cell," that is two spiral flows, one completely surrounding the other, having axial velocity components in opposite directions.

Many examples are given; in particular, even a three-celled motion is possible.

J. C. Cooke, England

5821. Hammitt, A. G., Dimensionless parameters for viscous similarity, AFOSR TN 60-226 (Princeton Univ., Dept. Aero. Engng. Rep. 491), 6 pp., Dec. 1959.

Viscous similarity of two flows can be achieved by matching Reynolds number only if viscosity is essentially constant throughout the flow. If large differences of static temperature occur and viscosity follows a two-parameter Sutherland law, then both Reynolds number and ratio of static temperature to Sutherland temperature must be matched. Errors of the order of factors of 2 or 3 in Reynolds numbers near the stagnation point can occur in hypersonic flows if no attention is paid to the second parameter.

From author's summary

5822. Kostiukov, A. A., On the lifting force of source and dipole in bounded fluid stream, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23,** 2, 547-550, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

Paper gives formulas (without derivation) for the vertical force on a source and upon a doublet moving at constant speed beneath the surface of a heavy fluid which has a finite depth. Author also quotes his results for the lateral force on a source moving parallel to a vertical wall in a liquid having finite depth. While formulas are of interest, numerical values are given only for the case of zero and infinite Froude number and hence have little practical value for towing-tank research which is generally concerned with Froude numbers at which waves are created when submerged bodies are towed sufficiently close to the free surface. Paper could have been much more useful if generalized to the case of a body of revolution and evaluated over the entire range of Froude numbers.

J. P. Breslin, USA

5823. Gheorghita, St. I., On the impact theory on perfect incompressible fluids (in English), *Rev. Physique* **4,** 1, 75-84, 1959.

Solutions are given to five problems in plane, incompressible, frictionless flow which are meant to represent the results of applying a uniform impulsive pressure, due to an underwater explosion, to the boundaries of some regions near the free surface. Conformal transformations are used and the solutions are given in terms of the complex velocity potential.

The velocity potential is taken as zero along the free surface line, and as constant along the boundaries of the regions of applied pressure. The boundaries are either segments of the free surface line or circular arcs below the free surface. The conformal transformations are adaptations of standard results.

G. Chertock, USA

5824. Fraenkel, L. E., Incompressible flow past quasi-cylindrical bodies and some associated problems, *Quart. J. Mech. Appl. Math.* **11,** 2, 212-222, May 1958.

Paper presents a neat solution of the incompressible flow past a slender body of revolution at zero incidence which may have discontinuities in its profile slope. The analysis follows Lighthill's method of dealing with corresponding problem in supersonic flow. A solution of the Laplace equation for the velocity potential is given in terms of a certain cylindrical harmonic whose properties are extensively investigated and numerical values tabulated. With the aid of this tabulated function the velocity or pressure distribution on the surface of the body can be easily and rapidly worked out.

A valuable paper which has useful applications to cone-cylinders in low-speed flow and to the problem of the vertical water-entry of a cone.

P. R. Owen, England

5825. Tipei, N., Some generalizations about laminar viscous flow (in French), 9th Congrès Inter. Mécan. Appl., Univ. Bruxelles 1957; **3,** 283-293.

Author examines carefully the orders of magnitude of terms in the Navier-Stokes equations with two classes of problem in view. The first is that of Stokes's flow, taking account of spatial and possibly temporal variations in viscosity; a simple example is that of a steady couette flow between walls at unequal temperatures, for which paper presents numerical results. The other class of problem includes the Reynolds theory of lubrication; here author extends the classical treatment by eliminating the assumption of a very thin lubricating layer. Throughout paper the fluid is treated as incompressible. P. R. Owen, England

5826. Sparrow, E. M., and Gregg, J. L., Flow about an unsteadily rotating disc, *J. Aero/Space Sci.* **27,** 4, 252-256, 290, Apr. 1960.

Results are given for axial velocity, shear and torque for laminar flow about an unsteadily rotating disk in an infinite medium in terms of the ratio of wheel speed to its rate of change and acceleration. Solution is given in terms of departure from steady-state solution due to Kármán. Results are from power series expansion on the parameters carried out to the second-order terms using a computer. Limits for use of steady-state solution to 5% accuracy or better for both laminar and turbulent flow are provided.

S. J. Kline, USA

5827. Gersten, K., On the calculation of the induced velocity field of wings (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 173-190.

Author's main desire is to present a method for simple numerical computation with adequate accuracy. Therefore the method is carried out under the assumption that the vortex sheet is not rolled up and lies in the wing plane. This assumption is not a necessary condition for the development of the theory nor does it impair the accuracy of the results for a great number of examples. For incompressible flow the induced velocity field for the downwash and sidewash is given in the entire space behind the wing by simple sum equations instead of the intricate integrals on the premise that load distribution on the wing has been calculated by lifting-line theory or the idealized lifting-surface theory (that is, the "lifting-surface theory" by H. Multhopp or E. Truckenbrodt). Besides general tabulated coefficients these sum equations only contain certain influence functions which may be taken directly from given diagrams, which are valid for downwash as well as for sidewash. Results can be generalized to subsonic flow by application of the Prandtl-Glauert rule. This transformation is also presented. F. W. Keune, Germany

5828. Ghildyal, C. D., On steady axially symmetrical superposable flows (in English), *Ganita* **10,** 1, 1-9, June 1959.

Criteria were developed for the mutual superposability of a rotational and irrotational flow in both viscous and nonviscous fluids in the case of axial symmetry.

W. L. Sibbitt, USA

5829. Sato, H., The stability and transition of a two-dimensional jet, *J. Fluid Mech.* **7,** 1, 53-80, Jan. 1960.

Mean velocity and fluctuation measurements in a two-dimensional free jet of air were taken by means of hot wires. The emerging jet was laminar. It was found that transition to turbulence was preceded by a region in which fluctuations of a well-determined frequency did occur. These fluctuations increase exponentially in streamwise direction. Both low-frequency antisymmetrical and high-frequency symmetrical fluctuations were observed. Frequencies increase with jet speed. Excitation of transition by means of sound waves was most effective at the frequencies of the two types of fluctuations.

Mean velocity profiles were different from the self-similar profiles of a fully developed laminar jet as the exit Reynolds number was of the order of 1000 or more. Numerical solution of the Orr-Sommerfeld equation, neglecting the viscous term and using the observed mean velocity profiles, yielded satisfactory agreement with the observed fluctuation patterns.

L. J. F. Broer, Holland

Book—5830. Schulz, F., and Fasol, K. H., Waterjet pumps for the transport of liquids [Wasserstrahlpumpen zur Forderung von Flussigkeiten], Wien, Springer-Verlag, 1958, vi + 73 pp. $3.55. (Paperbound)

This booklet deals with the characteristics of jet pumps. First, the theoretical considerations based on the momentum equation are given; then flow rate, velocity distribution and pressure distribution of jet pumps with air and water are measured. From these results are shown the effects of nozzle forms, the length of mixing chambers, distance of nozzle on the performance of jet pumps.

Particularly notable point of authors' experiments is that the experiments on curved nozzle pipe and curved diffuser pipe were conducted. Reviewer thinks this information contributes to designing more effective jet pumps. Further, reviewer believes it should be noted that Prof. Yoichi Takashima had studied jet pumps more widely than this paper in his doctoral dissertation, "Study on the dynamic characteristics, design and application of the ejector," Tokyo Institute of Technology, 1956.

T. Okamoto, Japan

5831. Timme, A., Properties of vortex streets (in German), Dtsch. Versuchsanstalt Luftfahrt, Ber. 77, 41 pp., June 1959.

Author examines the experimental results obtained on Kármán's vortex streets with the aid of a hot wire. An approximate calculation, in which the viscosity effect is taken into account according to Oseen-Hamel method, leads to values which are compared to the experimental data obtained through the latter method. A partial agreement is found. However, differences are also noted leading to the conclusion that, with the aid of a hot wire, the position of vortices which separate from a cylinder, and consequently a series of their characteristics, cannot be determined. On the contrary, if a separate vortex street is considered according to Wehrmann's method [D. V. L. Bericht no. 43, 1957], the signals obtained with the aid of a hot wire can be mathematically interpreted. Some differences are attributed by the author to the influence of the boundary layer which develops on the wall separating the vortex streets.

Final part of the paper compares some of the experimental results with C. C. Lin's theory of vortex evolution in a viscous fluid. A fairly good agreement is obtained only if the value of the kinematic viscosity is modified by multiplication with a turbulence factor and if the origin of the coordinate axes is changed. Author considers that this comparison may be a guide for future investigations on vortex streets in view of clarifying the transition from laminar to turbulent flow. T. D. Oroveanu, Roumania

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 5856, 5858, 5866, 5869, 5870, 5871, 5874, 5878, 5881, 5883, 5909, 5915, 5930, 5963, 5967, 6005, 6008, 6015, 6019, 6020, 6036, 6045, 6049, 6050, 6060)

5832. Wagner, R. D., Jr., Some aspects of the modified Newtonian and Prandtl-Meyer-expansion method for axisymmetric blunt bodies at zero angle of attack, *J. Aero/Space Sci.* **26,** 12, 851-852 (Readers' Forum), Dec. 1959.

Note presents useful curves and discussion of Lees' early suggestion [*J. Aero. Sci.* **24**, 3, 195-202, Mar. 1957] of matching the Newtonian pressure distribution with the Prandtl-Meyer relations at the point where both pressure and pressure gradient from these solutions agree. The location of the matching point, the Mach number at the matching point, and the pressure coefficient at the nose-cylinder junction are presented as functions of the free-stream Mach number for air (presumably for a γ of 1.4), and helium. Also shown are the pressure distributions from the stagnation point to the nose-cylinder junction for various free-stream Mach numbers. H. P. Liepman, USA

5833. Hicks, B. L., and Chenoweth, D. R., An exact calculation of some steady, diabatic, two-dimensional fields of compressible flow, *J. Aero/Space Sci.* **27**, 2, 142-144 (Readers' Forum), Feb. 1960.

5834. Popp, S., Compressibility correction on the problem of fluid flow along a symmetrical obstacle (in French), *C. R. Acad. Sci., Paris* **249**, 5, 619-221, Aug. 1959.

5835. Pien, Y.-K., The solution of Tricomi's equation for a transonic jet, *Scientia Sinica* **7**, 9, 946-963, Sept. 1958.

The boundary-value problem of a transonic jet formulated in the hodograph plane is to solve the Tricomi equation, $u_{xx} - xu_{yy} = 0$, in both subsonic (elliptic) and supersonic (hyperbolic) regions. It is known that this problem involving the mixed-type equation can be reduced to a purely elliptic type. Since the general solution is available in the hyperbolic region, a functional relation between the stream function and its derivative can be formed along the sonic line and serves as an additional condition for the flow in the elliptic region. However, a direct approach proves to be still difficult. This difficulty is overcome by constructing another functional relation based on the boundary conditions in the elliptic region. The two functional relations which must be compatible enable us to determine either the stream function or its derivative on the sonic line. Consequently, the original problem is reduced to an inversion of a singular integral equation of the Cauchy type. The inversion is carried out by using Carleman's method, which is to transform the singular integral equation into a Hilbert-Riemann problem. From author's summary by C. B. Ludwig, USA

5836. Dorodnicyn, A. A., A contribution to the solution of mixed problems of transonic aerodynamics, Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8-13, 1958), Pergamon Press, 1959, 832-844.

A brief account of a method of approximating to equations of compressible flow in form suitable for use on digital computers. The flow region is divided into suitable curvilinear strips and an integration across the strips yields a set of integral relations. The functions in the integrands are replaced by suitable interpolating polynomials so that a set of ordinary differential equations is obtained. (Essentially similar to Pohlhausen method for boundary layers.) When equations change from elliptic to hyperbolic across unknown sonic line uniqueness is obtained by demand of continuity of the solution—illustrated by a simple example. Results are presented for subsonic flow past ellipses and ellipsoids, ellipses with $M = 1$ and supersonic flow past circular cylinder (with detached shock). Results for latter are remarkably good. H. C. Levey, Australia

5837. Beane, Beverly J., and Landahl, M. T., A theoretical investigation of second-order supersonic interference effects, AFOSR TN 59-962 (Flygtek. Försöksanst. Rep. AU-II-93:1), 17 pp., 1959.

An approximate solution, valid for high Mach numbers, for the second-order supersonic flow problem of two interfering flow fields is given. The approximate solution requires that the spanwise curvature of the body flow field is small. A further approximation is made which leads to a very simple formula for the interference pressure. This formula is found to give relatively small errors in the cases investigated.

From authors' summary by J. H. Horlock, England

5838. Keyes, J. J., Jr., An experimental study of gas dynamics in high velocity vortex flow, Proc. Heat Transf. Fluid Mech. Inst., Stanford, Calif., June 15-17, 1960; Stanford Univ., 1960, 31-46.

This is an experimental investigation of a gas flow in a simple jet-driven vortex tube. Tubes of internal diameter varying from 0.64 to 2.00 in., and length from 3.5 to 12.0 in., were supplied with helium or nitrogen through nozzles uniformly spaced along the tube, or through a continuous slit. The radial static pressure distribution was measured at the closed end of the tube and the tangential velocities estimated on the assumption of the two-dimensional flow with uniform radial mass transport.

The instrumentation technique is more convincing than those previously used on Ranque-Hilsch-type tubes and cyclone separators although still open to a criticism. However, the velocity data correlate reasonably well with the inlet jet kinetic energy and the tangential Reynolds number.

Author concludes that vortexes generated were much closer to potential flow than to solid body rotational flow, although high turbulance levels were indicated by high values of the ratio of virtual viscosity to molecular viscosity.

S. Smoleniec, South Africa

5839. Waldman, G. D., Extended hypersonic small-disturbance theory, WADC TN 59-173 (Brown Univ., Div. Engng.), 78 pp., June 1959.

The first-order theory for steady inviscid hypersonic flow [developed by Van Dyke, AMR **7**(1954), Rev. 3951] is used to find a second-order solution for two-dimensional and axisymmetric flows. Theory is applied to simple cases (such as wedges, circular cones and the nose of an ogive) which involve only a single bow shock wave. For two-dimensional flow past a wedge, both direct and inverse methods of solution are discussed; the direct method (expanding in terms of the shock angle) is more accurate, but the inverse method (taking the shock angle as known) is more convenient. The second-order theory gives a significant improvement on first-order results for moderate and large values of the similarity parameter $M\delta$ (where δ is the flow deflection angle); however, as in the case of unmodified first-order theory, second-order results (with the inverse method) diverge from the exact values for small $M\delta$.

First-order theory is given for hypersonic flows past flat, planar conical bodies with attached shocks. It is shown that, to the first order, there is zero crossflow. A method is outlined for extending the second-order theory for flow past arbitrary thin or slender bodies. A. W. Babister, Scotland

5840. Feldman, S., Numerical comparison between exact and approximate theories of hypersonic inviscid flow past slender blunt nosed bodies, *ARS J.* **30**, 5, 463-468, May 1960.

The method of characteristics is used to obtain an exact numerical solution of the supersonic portion of the inviscid flow field around a hemisphere cylinder (about 75 radii long) flying at 60,000 ft and 17,500 ft/sec. The calculations were performed by an electronic computer and consider air as a real gas in thermodynamic equilibrium.

Results are given for the shock wave shape, the streamline and characteristics pattern, the pressure density and temperature profiles between the shock and body, and the pressure distribution along the body. These are compared with the results given by the free layer and first- and second-order blast-wave theories (see Hayes and Probstein, AMR **13**(1960), Rev. 1288). It is found that

only the second-order blast-wave theory gives reasonable results; and this is largely fortuitous since the energy per unit length is not constant, as is assumed in blast-wave theory. Author concludes that "if body shapes other than those considered here are of interest, the only reliable approach at the present time is to carry out numerical calculations."

G. A. Bird, Australia

5841. Adamson, T. C., Jr., Estimation of nonequilibrium reaction flight regimes for blunt bodies at hypersonic speeds, *ARS J.* **30,** 4, 358-360 (Tech. Notes), Apr. 1960.

5842. Whalen, R. J., Viscous and leading-edge effects in hypersonic flow, *J. Aero/Space Sci.* **27,** 5, 391-392 (Readers' Forum), May 1960.

5843. Treanor, C. E., A graphical solution for normal shock waves in real gases, *J. Aero/Space Sci.* **27,** 2, 158-160 (Readers' Forum), Feb. 1960.

The solution of the equations for conditions behind a normal shock in a real gas usually represents a tedius and time-consuming part of shock-tube research. Even for gases for which the thermodynamic properties have been calculated completely, the simultaneous solution of the Rankine-Hugoniot equations using graphs or tables of thermodynamic properties presents a formidable amount of numerical work.

Author gives a very interesting rapid graphical method of obtaining such solutions. The accuracy is limited only by the accuracy of the graph available for the gas properties. No iterative procedure is involved, and the only machine or slide-rule calculations required are for factors having to do with the initial conditions of the gas and the speed of the shock wave. The method employs a universal curve, an auxiliary piece of graph paper, and a plot of the thermodynamic properties of the gas, where lines of constant enthalpy are plotted on a graph of density versus pressure on log-log paper. An extension for calculation of conditions behind a reflected shock is also described.

C. Franze, Germany

5844. Moe, Mildred M., and Troesch, B. A., Jet flows with shocks, *ARS J.* **30,** 5, 487-489 (Tech. Notes), May 1960.

The initial slope of jet boundary from an axially symmetrical supersonic underexpanding nozzle is determined by matching the shock equations in the air and the Prandtl-Meyer relations in the jet. Downstream from the exit plane the boundary turns inward, causing a shock within the jet. The computation of the entire flow is based on the method of characteristics supplemented by the Rankine-Hugoniot relations for the shocks. Three results of the many calculated examples are shown in figures: Jet flow from a bell nozzle into still air; from a bell nozzle into supersonic airstream; from a conical nozzle into still air.

A. Betz, Germany

5845. Lambourne, N. C., Some instabilities arising from the interactions between shock waves and boundary layers, Aero. Res. Counc. Lond. Curr. Pap. 473, 38 pp., 1960.

A brief review is made of the available information concerning the flow fluctuations and instabilities arising from shock-induced separation in the flow over airfoils and wings. The influence this phenomenon has on the oscillatory behavior of airfoils and control surfaces is also briefly discussed.

A more detailed consideration is devoted to a recent investigation at the N. P. L. into the part played by shock-induced separation in the instability of a control surface.

From author's summary

5846. Fickett, W., and Wood, W. W., Shock Hugoniots for liquid argon, *Physics of Fluids* **3,** 2, 204-209, Mar./Apr. 1960.

Shock Hugoniots for liquid argon are calculated using equations-of-state obtained from the Monte Carlo method and the Lennard-Jones-Devonshire cell theory, using an experimentally determined pair potential. Agreement with presently available experimental data is poor.

From authors' summary

5847. Muckenfuss, C., Bimodal model for shock wave structure, *Physics of Fluids* **3,** 2, 320-321 (Letters to the Editor), Mar./Apr. 1960.

Book—5848. Dresden, M., Kinetic theory applied to hydrodynamics (Colloquium Lectures in Pure and Applied Science, no. 1, June 1956), Dallas, Texas, Field Research Laboratory, Magnolia Petroleum Co., 1957, 127 pp.

A reproduction of a set of nine lectures by a physicist on the kinetic theory foundations of the hydrodynamic equations for dilute gases, based primarily on the Boltzmann equation. There are no applications of the hydrodynamic equations to engineering or physical problems. The lectures are altogether charming, and although they contain considerable mathematics, they also contain much physical insight and many shrewd remarks. Most physicists could profit from reading these lectures. Engineers should probably be content to carry away the idea that there are several sets of hydrodynamic equations, all approximate, of increasing complexity, detail, and precision.

E. A. Mason, USA

5849. Soffker, E., Investigations of a supersonic inlet diffuser with a stabilizing ring (in German), *Z. Flugwiss.* **8,** 2, 33-44, Feb. 1960.

The working range of conventional conical multi-shock diffusers is considered in detail. The use of a stabilizing ring in front of the diffuser is found to lead to better pressure recovery and to extend the operating range. The flow pattern with external ring is discussed in detail and experiments at $M = 1.83$ are described.

N. H. Johannesen, England

5850. Englert, G. W., Operational method of determining initial contour of and pressure field about a supersonic jet, NASA TN D-279, 37 pp., Apr. 1960.

Using operational methods following G. N. Ward [AMR **9**(1956), Rev. 196], author obtains simple expressions for estimating initial contour of an axisymmetric jet exhausting into (a) supersonic stream, and (b) quiescent air. For various combinations of stream and jet Mach numbers as well as jet-to-free-stream pressure ratios, initial contours agree with characteristics solution and experimental data to within 10 per cent. The pressure distribution on a flat plate in the supersonic stream was computed, and results agree favorably with experimental data. For the case of jet exhausting into still air, differences between predicted initial contours and characteristics solution and experimental data were of the order of 20 per cent.

A. Ritter, USA

5851. Geiger, R. E., Short hypersonic contour nozzles, *ARS J.* **30,** 4, 368-369 (Tech. Notes), Apr. 1960.

5852. Salmi, R. J., Effects of jet billowing on stability of missile-type bodies at Mach 3.85, NASA TN D-284, 17 pp., June 1960.

An experimental investigation was conducted at the NASA Lewis 2- by 2-foot Mach 3.85 wind tunnel to determine the interference effects of jet billowing on the forces and moments of two missile-type bodies. High-pressure nitrogen was exhausted through an annular sonic jet to simulate a rocket exhaust. In general, the interference effects improved the stability of the bodies. Forces, moments, and schlieren observations are presented.

From author's summary

5853. Lick, W., Inviscid flow of a reacting mixture of gases around a blunt body, *J. Fluid Mech.* **7,** 1, 128-144, Jan. 1960.

Paper describes an inverse method which determines the details of the flow around an axisymmetric blunt body by a numerical calculation of the flow field behind a detached shock wave of prescribed shape. The equations which govern this flow field are presented for a dissociating and recombining mixture of gases and the solution is by a step-by-step process using an electronic computer. A rough analysis is made of the dissociation and recombination rates for oxygen and nitrogen and these are applied to the computation of the flow in one example for pure oxygen and in three examples for an idealized air model. The shock radius in the examples for air is varied so that a typical dissociation relaxation distance in comparison with the shock detachment distance is either small (almost equilibrium flow), of the same order, or very large (frozen flow). G. A. Bird, Australia

Boundary Layer

(See also Revs. 5811, 5826, 5845, 5870, 5960, 5969, 5970, 5971, 6012, 6014, 6015, 6020, 6028, 6083)

5854. Muesmann, G., Measurements and boundary layer observations on thickened compressor blades as a function of Reynolds number (in German), *Z. Flugwiss.* **7,** 9, 253-264, Sept. 1959.

Measurements of lift, drag and pitching moment were made on a series of four related airfoils, with flat pressure faces and thickness ratios from 8 to 20%. Aspect ratio was 5 but results were corrected to infinite aspect ratio. Mach number was small and Reynolds number varied between 0.17×10^5 and 4×10^5.

Critical changes of force and moment were observed at Reynolds number of about 1×10^5, with hysteresis as Reynolds number was increased and decreased at constant incidence. Separation and transition of boundary layer were studied by evaporation of naphthalene and by stethoscope, as an aid to interpretation of observed force changes. W. A. Mair, England

5855. Rozin, L. A., Approximate method of computation of the nonstationary turbulent boundary layer in an incompressible liquid, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22,** 6, 1208-1216, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The integral momentum equation for nonsteady state is employed with judicious assumptions regarding the nature of the velocity profile to infer some important features of boundary layers including boundary layer separation and growth rate. The important assumption is that the effective layer depths for momentum and for momentum transport are proportional. Two specific examples of the general method of attack are discussed.

R. O. Reid, USA

5856. Bradfield, W. S., Conical turbulent boundary layer experiments and a correlation with flat plate data, *ASME Trans.* **82** C (*J. Heat Transfer*), 2, 94-100, May 1960.

Paper presents experimental measurements of total temperature profiles, directly determined skin friction, and local heat flux in the turbulent boundary layer of an unyawed cone model at Mach numbers 1 to 6. Total temperature profiles plotted as y/δ_t vs $T_o(y)/T_{o1}$ are similar to two-dimensional profiles. Over wide Reynolds and Mach ranges, velocity data are well represented by 1/7 power law for outer region of boundary layer in combination with linear profiles for the laminar sublayer.

Assuming congruence of plate and cone velocity profiles at same M and same form of friction law, author derives ratio of $C_f/\bar{C}_f$ in terms of n, at same M, u_t/ν_t and, $x = \bar{x}(n = 7$ in 1/7 power law) where C_f = cone friction coefficient and $\bar{C}_f$ = plate friction coefficient. Using Reynolds analogy and reference temperature defined by Eckert, author shows $St/\bar{St} = C_f/\bar{C}_f = 1.18$ (for $n = 7$).

Results permit calculation of turbulent friction and heat transfer on unyawed cones at supersonic speeds by means of an incompressible plate friction law. Results check with experimental data. J. G. Knudsen, USA

5857. Scott, C. J., Integral laminar boundary layer solutions using the Crocco variables, AFOSR TN 59-1304 (Univ. Minn. Inst. Technol., Rosemount Aero. Lab., Engng. Memo no. 86), 19 pp., Aug. 1959.

Conventional boundary-layer equations for a thin compressible laminar boundary layer with no pressure gradient and for a perfect, single component gas with constant Prandtl number and specific heat are solved by the approximate integral methods. As usual in the use of integral methods, the objective here is to provide an engineering approximation of effects (i.e., skin friction and heat transfer) rather than to provide a study of boundary-layer structure.

Author treats in detail several special injection cases which yield analytical solutions and points out that more arbitrary cases may be treated by numerical methods. Reasonable agreement is shown with more exact analyses in cases where similarity exists.

Large injection rates must be considered with caution since, as pointed out by the author, the boundary-layer approximations (i.e. "thin" layer) no longer provide an adequate description.

J. D. Whitfield, USA

5858. Stivers, L. S., Jr., Effects of fixing boundary-layer transition for a swept and a triangular-wing and body combination at Mach numbers from 0.60 to 1.40, NASA TN D-312, 28 pp., June 1960.

The wings had an aspect ratio of 2.99 and 3-percent-thick biconvex sections. Lift, pitching-moment, and drag data were obtained at Mach numbers from 0.60 to 1.40 for angles of attack from 2° to about 15°. The Reynolds number for the tests was generally 1.5 million; however, minimum drag data were obtained for both configurations over a range of Reynolds numbers from 1.0 million to about 3.0 or 4.0 million. From author's summary

5859. Waiter, S. A., Reduction of the boundary layer thickness in a hypersonic nozzle, AFOSR TN 60-514 (Univ. So. Calif. Engng. Center Rep. 56-213), 22 pp., May 1960.

The reduction of the boundary-layer thickness in a hypersonic nozzle can be realized by cooling the walls; in this way, an important heat transfer from the flow is created, increasing the density in the boundary layer. The integration of the mass flow equation will show the influence of the wall temperature on the boundary-layer thickness.

Applications to specific cases are proposed for a given nozzle. The following results are observed: (1) The power needed for cooling the nozzle is low; (2) This power varies slowly with the wall temperature (if $T_w < 200°K$) but decreases with the Reynolds number and the stagnation temperature for a given Mach number. Charts are given for $8 \leq M \leq 18$ and for stagnation temperature $T_s \leq 2000°K$. For higher temperatures, dissociation and ionization appear, so the problem must be solved for each special case; the general heat-transfer equation is given and its application is easy if the stagnation conditions and the local Mach number are known.

From author's summary

5860. Eppler, R., Boundary-layer separation and wake formation (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 238-247.

Author's method for calculating Kirkhoff-type inviscid flows past a bluff body [AMR **8**(1955), Rev. 706] gives a range of separation positions, in general, for any prescribed under-pressure in the wake. Two arguments are proposed here to identify physically significant flows among the solutions obtained, concerning their internal consistency and their compatibility with criteria for boundary-layer separation.

Consideration of the case of the circular cylinder leads to the suggestion that for some bodies boundary-layer criteria for separation may not be relevant, because no wake solutions compatible with them exist. Reviewer draws attention to author's acknowledgement that this idea cannot be substantiated without further development of the wake theory and more experimental evidence.
E. P. Sutton, England

5861. Schlichting, H., Recent developments in boundary layer control (in German), Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8-13, 1958), Pergamon Press, 1959, 563-586.

Recent work at the DFL and AVA is described. The turbulent boundary layer growth over airfoils with full-chord suction or blowing through the surface has been calculated. Neutral stability curves of laminar boundary layers behind suction slots have been evaluated. The effect of fences on the span-load distribution of a constant-chord swept wing has been measured and analyzed.
G. E. Nitzberg, USA

5862. Lachmann, G. V., Fundamental design problems of aircraft with boundary layer control for maintaining laminar flow, Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8-13, 1958), Pergamon Press, 1959, 587-619.

The potential gains and problems associated with maintaining extensive laminar flow are considered. For a conventional turbojet airliner the lift-drag ratio would be doubled if the flow over wings and tail were made fully laminar. The engineering problems include the integration of jet engine and suction pumps into a by-pass system and the design of wing structures to provide suction openings and ducting. G. E. Nitzberg, USA

5863. Carriere, P., Eichelbrenner, E., and Poisson-Quinton, Ph., Theoretical and experimental study of boundary layer control by blowing *(in French),* Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8-13, 1958), New York, Pergamon Press, 1959, 620-661.

Measurements were made to determine the effect of blowing over a flat surface on boundary-layer velocity profiles. Both uniform and adverse pressure gradients in low-speed two-dimensional flow were investigated. It is found that these complex flows can be described by a simple adaptation of classical jet theory.

On the basis of two-dimensional tests of blowing flaps, several practical criteria for predicting performance were deduced. The parameters considered include flap chord and deflection, location of blowing nozzle, and blowing momentum coefficients. The criteria are applied to swept and unswept wings of finite span.
G. E. Nitzberg, USA

5864. Hurley, D. G., The use of boundary-layer control to establish free stream-line flows, Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8-13, 1958), Pergamon Press, 1959, 662-708.

The basic idea was to improve the low-speed performance of thin wings by exploiting rather than suppressing leading-edge separation. A forward facing flap was mounted on the upper surface of the wing and the separated flow was made to reattach and remain attached to the flap surface by use of boundary-layer control. A theoretical and experimental investigation of the potentialities of this scheme is described. The model tested had the hinge line at the airfoil trailing edge. The flap extended forward two-thirds of the chord and had blowing boundary layer at the leading edge. The lift coefficients obtained, for equal blowing quantities, are similar to those for an NACA 23015 airfoil with a blowing flap deflected 45°. G. E. Nitzberg, USA

5865. Woodley, J. G., Measurements of the effect of surface cooling on boundary layer transition on a 15-degree cone, Part 2: Tests at M = 3 and M = 4 in the 5-in. × 5 in. no. 5 wind tunnel at R. A. E. Farnborough, Aero. Res. Counc. Lond., Curr. Pap. 479. 37 pp., 1960.

Tests on a steel cone with an included angle of 15° showed that the increase in transition Reynolds number with surface cooling at zero incidence was greater at a local Mach number (M_1) of 2.93 than at $M_1 = 3.48$.

When the cone was set at an incidence of +2°, transition on the windward side moved aft with cooling at the lower Mach number at approximately the same rate as was found in the zero incidence tests. However at both Mach numbers, little, if any, movement could be seen on the leeward generator. The range of stagnation pressures available did not allow a study of transition to be made on the windward generator at the higher Mach number.

Simultaneous records of transition position on the top and bottom generators of the cone were obtained for all these tests, using the shadowgraph technique. From author's summary

5866. Covert, E. E., Some approximations to the solution to the binary boundary-layer problem, AFOSR TN-59-1091 (Mass. Inst. Technol., Naval Supersonic Lab. TR 390), 23 pp., Sept. 1959.

Integral boundary-layer equations of mass conservation, momentum, and energy are set out for binary gas flow with arbitrary external velocity, blowing distribution, and wall temperature. Methods for finding approximate solutions are presented based on assumption of similarity among several integrands in the developed system of equations. Results are compared with some exact solutions. Error due to basic assumption can be large in some circumstances, but the approximate analysis delivers correct orders of magnitude. A. H. Shapiro, USA

Turbulence

(See also Revs. 5811, 5815, 5829, 5831, 5838, 5856, 5870, 5984, 6083, 6087)

5867. Shinnar, R., and Church, J. M., Statistical theories of turbulence in predicting particle size in agitated dispersions, *Indust. Engng. Chem.* **52,** 3, 253-256, Mar. 1960.

Turbulence on a small enough scale to affect dispersion is presumed isotropic even though this is not so throughout an agitator. Basic relations of isotropic turbulence and of energy dissipation are applied to published results for the breakup of droplets and of gas bubbles in a stirred tank, yielding equations or correlations that are useful in the scaling-up of such equipment. The scale-up principle of equal energy input per unit volume is derived from local isotropy, showing that it is theoretically justified for dispersions. Kolmogoroff's statistical theory can predict particle size in liquid-liquid dispersions. C. F. Bonilla, USA

5868. Hayasi, N., An improved hot-wire anemometer, Rep. Transport. Tech. Res. Inst., Tokyo (Unya Gijutsu Kenkyujo), no. 36, 45 pp., July 1959.

In the first part author re-examines some of the finer points in the calibration of the hot-wire anemometer used for the classical turbulence measurement (essentially zero Mach number, only longitudinal velocity component is measured, no temperature or chemical concentration fluctuation is considered).

In the second part author's new hot-wire anemometer equipment is described. Thermal lag compensation is improved (ceiling-to-floor ratio is 1100). Frequency band is adequate for low-speed

flow turbulence (11 kc). For mean-square measurements a thermistor is used, followed by an RC integrator. Sample turbulence measurements are given showing reduced scatter even with widely varying wire overheat. L. S. G. Kovasznay, USA

5869. Datar, S. G., Temperature response of a hot-wire anemometer to shock and rarefaction waves, Univ. Toronto, Inst. Aerophys. TN-28, 36 pp., June 1959.

The adaptability of the hot-wire anemometer in the study of temperatures behind the incident and reflected shock waves and incident and reflected rarefaction waves is examined. The measured temperatures in both cases show good agreement with theory at low diaphragm pressure ratio. Brief theoretical account of shock, rarefaction waves and hot-wire anemometer is given.

The results obtained do not seem encouraging. A further investigation will be needed, especially on the temperature response of the wires. M. Kataoka, Japan

Aerodynamics

(See also Revs. 5559, 5599, 5827, 5832, 5835, 5839, 5840, 5848, 5849, 5852, 5853, 5855, 5856, 5928, 5929, 6045, 6053, 6054, 6055)

Book—5870. Kuethe, A. M., and Schetzer, J. D., Foundations of aerodynamics, 2nd ed., New York, John Wiley & Sons, Inc., 1959, xiv + 446 pp. $11.75.

Book is divided into three main sections.

First section (Chapters 1-6) deals with flow of incompressible fluid and is substantially the same as the first edition [AMR **4**(1951), Rev. 2554]. The momentum theorem has, however, been presented in a different and more satisfactory manner.

Second section (Chapters 7-11) is devoted to the flow of compressible fluid. The chapter on energy relations has been considerably modified, and a section indicating the effect of friction and heat addition on a one-dimensional flow has been added. The two-dimensional thin-wing theory has been replaced by the supersonic source method for the determination of the aerodynamic characteristics of a supersonic finite wing. The effect of sweep on drag is also discussed.

Third section (Chapters 12-16) is confined mainly to viscous laminar and turbulent boundary-layer flow. Considerable rearrangement of presentation has taken place, with a reduced account of isotropic turbulence, but theory on effect of compressibility has been extended, and includes Polhausen solution of flat plate temperature recovery and heat transfer problems. Short account of incompressible fluid flow in three-dimensional boundary layers is also given.

There are four appendices (a new appendix gives descriptive account of real fluid effects in high-speed flight), problems, tables, charts, subject index at end of book. A welcome addition is a detailed list of contents with section headings for each chapter at the beginning.

Copious footnote references should stimulate further reading. A striking feature is emphasis placed on precise statements of approximations made in setting up theories, e.g. in connection with linearized compressible fluid flow equations of motion of Chapter 11, and boundary-layer approximations of Appendix B. No consistent use of vector analysis is made, but the notation is used whenever possible. There are few minor typographical errors, two outstanding ones are the orientation of Fig. 5 on page 54, and δ_1 and δ_2 should be interchanged in Eq. [4] of page 79.

Within the limits set by the authors the book forms an excellent text on the foundations of aerodynamics, suitable for advanced undergraduate and graduate students. No previous knowledge of aerodynamics is assumed. E. E. Jones, England

5871. Kogan, A., On supersonic flow past thick airfoils, AFOSR TR 59-64 (Technion Res. and Develop. Found., Ltd., Haifa, Israel, Final Rep.; ASTIA AD 217 033), 37 pp., Feb. 1959.

Pressure distribution on a 10%-thick parabolic biconvex airfoil section at undisturbed flow Mach number 10, and four stepwise angles of attack from 0° to 30° was subjected to a practical, simplified method of analysis. Vorticity of flow behind the leading-edge shock wave is considered using Crocco's stream function for rotational supersonic flow past airfoils. Near-shock-detachment flow is subjected to an approximation method in the region between the airfoil and the shock wave.

Correlation with work of major earlier researchers who studied related subjects is presented in a well-organized derivation. Customary assumption of an ideal perfect gas flow is made, although the presented method does offer ready modification to real gas problems.

The competent mathematical treatment and the stipulated cases shown in graphical form constitute an interesting contribution for engineering applications dealing with studies of thick airfoils applicable for supersonic flight. C. R. Bell, USA

5872. Weissinger, J., Some results from the theory of ring airfoils in incompressible flow (in German), Advances in Aeronautical Sciences, Vol. 2 (Proc. of the First International Congress of the Aeronautical Sciences, Madrid, Sept. 8-13, 1958), Pergamon Press, 1959, 798-831.

Paper is an excellent critical review of the most important theoretical problems of ring airfoils undertaken by the author since 1954.

The potential flow ring airfoil theory investigation, giving pressure and velocity distributions, may be considered as completed and yields good results without unduly large numerical work. Simple formulas are deduced for over-all forces and moments, giving very good agreement with experimental results.

Two cases of interference effects are reported: central infinite circular body and shrouded propeller. Some further work on interference problems seems indicated.

Preliminary results on viscous flow effects—boundary layer and drag in axisymmetric flow and asymmetric flow—are included. These problems are least developed.

The comparison of author's results and those obtained by others and particularly with experimental investigations is very useful.
W. Fiszdon, Poland

5873. Vasavada, P. A., Chordwise variation of position of maximum thickness of a symmetrical hyperbolic aerofoil profile, *J. Aero. Soc. India* **10,** 3, 50-55, Aug. 1958.

It is a well-known fact that the pressure distribution has a tendency to be uniform by shifting back the position of maximum thickness of airfoil profile. This paper represents an attempt at obtaining some control of the position of maximum thickness. First, the method of calculating the relation between the pressure distribution and the airfoil profile is shown, and then author gives the method of controlling the position of maximum thickness. Reviewer thinks this paper will contribute to improved design of airfoil profile. T. Okamoto, Japan

5874. Tirumalesa, D., Lift interference for low aspect ratio wings in transonic wind tunnels, *J. Aero. Soc. India* **11,** 4, 79-82, Nov. 1959.

The theory of R. T. Jones for the lift on low-aspect-ratio wings has been applied to calculate the lift interference in transonic wind tunnels. It is shown that the correction to be applied to the angle of incidence is twice the correction obtained by Prandtl's theory in incompressible flow for large-aspect-ratio wings.
From author's summary by J. R. Spreiter, USA

5875. Nonweiler, T. R. F., Lift-curve slope and induced drag factors of large aspect ratio straight-tapered wings, *J. Roy. Aero. Soc.* **64,** 592, 224–225 (Technical Notes), Apr. 1960.

5876. Hafer, X., Aerodynamic investigations with wing-body combinations (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 191-207.

Paper deals with theoretical computations (1) of normal-force and moment of slender axisymmetrical bodies, (2) of location of aerodynamic center of wing body combinations. First part considers the distribution of lift and normal force along body-length in frictionless flow and with friction. In the latter case it is necessary to define an "effective body-thickness." This is done by adding the boundary-layer displacement thickness and defining a minimum displacement thickness at the rear part of body. In the second part bodies have been combined with swept and delta wings of large and small aspect ratios. Discussed are: the fuselage in the flow field of the wing, the influence of the front part and rear part of the fuselage, the influence of change of the wing planform in the fuselage region, the change of wing incidence from the fuselage flow field. For each of these cases, the shift of the aerodynamic center has been calculated. After adding these influences comparison of theoretical results shows good agreement with experiments for different wing-body combinations: (a) for swept wings of aspect ratio 5 with an elliptical body of revolution 1 : 7 and different swept angles; (b) for different front and rear locations of a rectangular wing with the same body of revolution as in (a); (c) for a 50° swept wing of aspect ratio 2.75 with a body of revolution of elliptical front part and parabolic rear part; (d) for a delta wing of aspect ratio 2.33 and taper ratio 0.125 with the same body of revolution as in (c). Theoretical investigations have been extended to compressible flow. It is shown that aerodynamic center shift for the fuselage alone is unchanged but the shift is reduced with increasing wing-body combinations.

F. W. Riegels, Germany

5877. Von Baranoff, A., Effects of interaction due to vortex sheets according to slender-body theory (in French), ONERA Pub. 72, 3–10, Sept./Oct. 1959.

The aerodynamic effects due to vortex sheets originated from wings at front and acting on those in the rear are calculated by the method of slender-body theory. Problem is further simplified by replacing vortex sheets by a system of concentrated vortices. It is shown that force and moment can be expressed in terms of circulations of the vortices. The formulas derived agree with those arrived at by previous authors. Y. H. Kuo, China

5878. Becker, E., and Wedemeyer, E., Measurements on five aerofoils of different planforms at high subsonic velocities (in German), *Z. Flugwissen.* **8,** 2, 44–52, Feb. 1960.

5879. Jones, R. T., Aerodynamic design for supersonic speeds, Advances in Aeronautical Sciences, Vol. 1 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958); New York, Pergamon Press, 1959, 34–51.

This paper competently summarizes the theoretical guide-lines for supersonic wing and wing-body design. Partly because of the long delay in publication (nearly two years) and partly because of the availability elsewhere of much of the material, it seems to this reviewer that the paper will be of interest principally to students or newcomers to the field. J. V. Becker, USA

5880. Collar, A. R., A closed formula for the drag of a flat plate with transition in the absence of a pressure gradient, *J. Roy. Aero. Soc.* **64,** 589, 38–39 (Tech. Notes), Jan. 1960.

5881. Miele, A., Minimal maneuvers of high-performance aircraft in a vertical plane, NASA TN D-155, 37 pp., Sept. 1959.

A general theory is presented for analyzing minimal maneuvers of high-performance aircraft in a vertical plane where the earth is assumed flat and the gravitational field uniform. The calculus of variations is used. For the general problem of simultaneously optimizing the angle-of-attack program and the thrust program, solutions in a closed form are not possible. Thus the integration of the set of Euler equations and constraining equations is to be performed by approximate methods. Under particular assumptions, however, expressions in a closed form can be derived for the optimizing condition. As an example, the brachistochronic climbing technique of a rocket-powered aircraft is readily computed if the induced drag can be neglected. As another example, the climbing technique of minimum time or of minimum fuel consumption for a turbojet aircraft is also readily computed by neglecting centripetal accelerations. To complete the paper, and to establish a link between calculus of variations and ordinary theory of maxima and minima, some quasi-steady problems (neglecting acceleration terms) are considered.

From author's summary by G. Schulz, Germany

5882. Gates, S. B., and Thorpe, A. W., An analysis of steady straight flight with inclined thrust, Aero. Res. Counc. Lond. Rep. Mem. 3096, 32 pp., 1959.

A relatively comprehensive analysis of thrust criteria for a supersonic vertical take-off and landing aircraft (at conventional attitude) with jet propulsion in all major modes of flight. Performance diagrams for low speed as well as for supersonic speed range (up to Mach number 2) are presented with appropriate vectorial analysis, which yields a very illustrative derivation of the prerequisites for the subject task. The handling problems and those of operational cost have been recognized but not subjected to a detailed examination. Principal case of the subject example treats a thrust-to-weight ratio increase from 0.75 to 1.50 which doubles the rate of climb and contributes to a 20% increase of level speed. A range of incidence studied for such aircraft with fixed attitude is between 10 and 90 degrees.

This paper represents a competent contribution to the contemporary optimization efforts in development of advanced aircraft for minimum airfield facilities and unconventional take-off and landing techniques. C. R. Bell, USA

5883. Fisher, L. R., Equations and charts for determining the hypersonic stability derivatives of combinations of cone frustums computed by Newtonian impact theory, NASA TN D-149, 33 pp., Nov. 1959.

Equations and charts of axial force coefficients and stability derivatives are derived and presented for cone frustums on the basis of Newtonian impact theory. A procedure is given whereby the charts may be used to obtain the stability derivatives of a missile shape built up of more than one cone frustum, or having a spherical nose together with one or more cone frustum.

E. K. Parks, USA

5884. Polhamus, E. C., Effect of flow incidence and Reynolds number on low-speed aerodynamic characteristics of several noncircular cylinders with applications to directional stability and spinning, NASA TR R-29, 25 pp., 1959.

See AMR **11**(1958), Rev. 3678.

5885. Huss, C. R., and Donegan, J. J., Effect of the proximity of the wing first-bending frequency and the short-period frequency on the airplane dynamic-response factor, NASA TR R-12, 20 pp., 1959.

See AMR **12**(1959), Rev. 477.

5886. Cheverton, B. T., Icing flight development, *J. Roy. Aero. Soc.* **63,** 587, 659–668, Nov. 1959.

Vibration and Wave Motion in Fluids

(See also Revs. 5807, 5810, 5822, 5823, 5931, 6004, 6008, 6025, 6045, 6050, 6082, 6086, 6124, 6125)

5887. Thurston, G. B., Theory of oscillation of a viscoelastic fluid in a circular tube, *J. Acoust. Soc. Amer.* **32,** 2, 210-213, Feb. 1960.

The hydrodynamic theory for the axial sinusoidal oscillation of a viscoelastic fluid in a rigid tube of an infinite length is given. An equation for the velocity profile is developed and typical profile curves are presented. Equations for the acoustic impedance per unit length of tube are also obtained. Functions from which the acoustic resistance and reactance are directly obtainable are determined and presented in graphical form.

R. C. Binder, USA

5888. Reid, W. H., The oscillations of a viscous liquid drop, Brown Univ., Div. Appl. Math. TR 32 (Contract Nonr-562(07) (NR-062-179), 7 pp., Feb. 1960.

Small oscillations of a liquid globe have been analyzed by Lamb and by Chandrasekhar [*Proc. Lond. Math. Soc.* 1959, p. 141-149] for arbitrary viscosity and forces, which produce the tendency to spherical form, due to self-gravitation.

Author shows that these general results are likewise valid when these forces are due to surface tension. By means of a clever combination of factors, the boundary condition containing surface tension and viscosity could be written as a relation which is identical in form with the corresponding boundary condition for a self-gravitating sphere. H. J. Schoemaker, Holland

5889. Reid, W. H., The effects of surface tension and viscosity on the stability of two superposed fluids, Brown Univ., Div. Appl. Math. TR-29 (Contract Nonr-562(07) (NR-062-179)), 31 pp., Nov. 1959.

General discussion of quartic characteristic equation [AMR **11**(1958), Rev. 147], shows all possible modes of stability or instability of interface between fluids of equal viscosity extending to infinity. Illustrative investigation in detail shows both stable and unstable modes if density of lower fluid is zero, the typical oscillatory modes and two aperiodic viscous modes if density of upper fluid is zero.

Author discusses Chandrasekhar's variational principle [*Proc. Cambr. Phil. Soc.* **51,** 1, 162-178, Jan. 1950]—an approximation for fluids not extending to infinity—and shows it to be not generally applicable. H. J. Schoemaker, Holland

5890. Landweber, L., and Macagno, Matilde, Added mass of a rigid prolate spheroid oscillating horizontally in a free surface, *J. Ship Res.* **3,** 4, 30-36, Mar. 1960.

Assuming a potential flow, authors examine the semisubmerged spheroids oscillating horizontally in a free surface with small amplitude. [See also T. H. Havelock, *Quart. Trans. Inst. Nav. Arch.* **95,** 1953]. The inertia coefficient is derived and approximated. L. N. Tao, USA

5891. Miles, J. W., On the generation of surface waves by shear flows, Parts 2 and 3, *J. Fluid Mech.* **6,** 4, 568-598, Nov. 1959.

Part 2 is essentially an extension of a previous paper [AMR **12**(1959), Rev. 1977] by the same author. The pertinent differential equation is solved more accurately, the imposition of the boundary condition at the interface rather than at its mean position is shown to give the same results, and inclusion of the dominant term in the Orr-Sommerfeld equation representing viscous effects (while Reynolds stresses in the turbulent wind are neglected!) is shown to have only a small effect.

Part 3 is a discussion of Kelvin-Helmholtz instability when the mean wind velocity varies with height. The usual variational method (of Rayleigh and Ritz) is applied to the well-known differential system (a Sturm-Liouville system) governing the stability problem to obtain the minimum representative wind speed for instability. The result is stated to be less relevant to the air-water case than to the case of air blowing over a very viscous liquid. But the viscosity of the liquid plays no part in the author's determination of the critical wind speed because, aside from the calculation of the amplitude of wind pressure from the equations governing air motion, the mathematical apparatus [Eq. (1.46)] used for this determination is exactly the same as that for the Kelvin-Helmholtz model for inviscid fluids. Therefore, on the strength of the theory *alone*, one cannot decide, for a given wind profile theoretically capable of producing K-H instability, how large the viscosity of the liquid has to be before such instability becomes physically significant. C.-S. Yih, USA

5892. Roseau, M., Short waves parallel to the shore over a sloping beach, *Comm. Pure Appl. Math.* **11,** 4, 433-493, Nov. 1958.

Author treats the problem of waves whose direction of motion is parallel to a sloping beach. The linearized equations are used and the water is treated as an ideal incompressible fluid. The method consists in representing the velocity potential as an integral in a complex plane, virtually a generalized Laplace transformation. While the author discusses the singularities and methods available for handling this integral, the results are left in a form which is not immediately comparable with experiment. No discussion is given of how far the linearized theory is valid at the shore line. J. M. Jackson, Scotland

5893. Fontanet, P., Second order approximation of the theory on the generations of waves with a pivoting flat board (in French), *C. R. Acad. Sci., Paris* **249,** 14, 1186-1188, Oct. 1959.

5894. Fontanet, P., Second order solution of the problem of the generation of cylindrical waves by a pivoting flat board (in French), *C. R. Acad. Sci., Paris* **249,** 16, 1450-1452, Oct. 1959.

5895. Takano, K., Second order effects caused by a semi-indefinite sill on a non-rotational wave (in French), *C. R. Acad. Sci., Paris* **249,** 5, 622-624, Aug. 1959.

5896. Takano, K., Approximate calculation of the linear effects of a wave passing over a sill (in French), *C. R. Acad. Sci., Paris* **249,** 14, 1189-1190, Oct. 1959.

5897. Roseau, M., On a problem of propagation of fluid waves in porous media (in French), *C. R. Acad. Sci., Paris* **249,** 16, 1453-1455, Oct. 1959.

5898. Roseau, M., Results of uniformity, singular solutions and generalizations of a problem of liquid waves in porous media (in French), *C. R. Acad. Sci., Paris* **249,** 17, 1611-1613, Oct. 1959.

5899. Moiseev, N. I., On the theory of elastic oscillations of a fluid-filled body, *Soviet Phys.-Doklady* **4,** 4, 806-809, Feb. 1960. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **127,** 1, 51-55, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Author has studied elastic vibrations of a beam-life body in the interior of which is a cavity of arbitrary shape either partially or completely filled with an ideal incompressible fluid. Within the assumptions of simple beam theory, author derives formal solutions for infinitesimal torsional and flexural beam modes of vibration of the body. In addition, it is assumed that motion of the fluid, which is excited by the beam oscillations, can be represented by a potential and that the amplitudes and velocities of the fluid waves

are infinitesimal. Equations of motion are derived by using Hamilton's principle and suitably defined operators. Author establishes use of Ritz method to calculate natural frequencies and eigenfunctions. D. F. Muster, USA

5900. Eisenmenger, W., Dynamic properties of the surface tension of water and aqueous solutions of surface active agents with standing capillary waves in the frequency range from 10 kc/s to 1.5 mc/s (in English), *Acustica* **9**, 4, 327-340, 1959.

In the frequency range from 10 kc/s to 1.5 Mc/s standing capillary waves are excited on the plane surface of water and aqueous solutions of surface active substances by means of rheolinear oscillations. Taking the theory of rheolinear oscillations as a basis, a method for measuring a surface viscosity is developed. The measured value for water is by one order of magnitude smaller than a value given in the literature. Another result is that some aqueous solutions of surface active substances have a noticeably higher surface viscosity. It is further shown that for water (frequencies about 1 Mc/s) as well as for aqueous solutions of surface active substances (lower frequencies) there exists an increase of the capillary wavelength and thereby also of the temporal mean value of the surface tension with rising capillary wave amplitude.

From author's summary by G. H. Lean, England

5901. Emblik, E., Momentum forces in pipe lines (in German), *Kältetechnik* **12**, 4, 94-96, Apr. 1960.

Bends in the discharge line of reciprocating compressors are subjected to relatively strong momentum forces that may lead to pulsations within the discharge pipes. An analytical prodedure is described by means of which the momentum forces may be determined. From author's summary

5902. Williams, T. J., Induction ramming of reciprocating engines, *Engineering* **187**, 4854, 370-372, Mar. 1959.

In this investigation, an attempt has been made to supplement existing experimental information on title subject and to develop a simple theory to analyze the results so as to give some indication of the engine speeds and induction pipe lengths at which good and bad conditions can be expected with single-cylinder engines.

From author's summary

5903. Keller, H. B., Levine, D. A., and Whitham, G. B., Motion of a bore over a sloping beach, *J. Fluid Mech.* **7**, 2, 302-316, Feb. 1960.

A detailed numerical study of the form of a bore advancing into still water of variable depth bears out an approximate analytical formula derived earlier by Whitman. The approximate system of analysis is based upon the differential equation for the rate of change of $u + 2\sqrt{gb}$ along a positive characteristic for which $dx/dt = u + \sqrt{gb}$, u being the speed of fluid and b the depth behind the bore. By employing the bore conditions—continuity of mass and momentum transport across the bore—it is possible to relate u and b to the bore speed U and the still water depth b_0 just ahead of the bore. Inserting these relations in the differential equation for $u + 2\sqrt{gb}$ yields an equation for the rate of change of U with b_0 or alternatively an equation for the rate of change of the bore height η with b_0. The resulting relations indicate that if the initial bore height η_1 is less than a critical value $0.626\ b_0$ then the bore height first increases then ultimately decreases like $b_0^{1/2}$ as b_0 tends to zero. The bore speed on the other hand decreases initially then increases to a finite maximum value at shore. If the initial bore height is greater than the critical value then the height decreases all the way to shore.

A finite difference scheme using a uniform space interval and incorporating a special procedure for fitting in the bore position at each time step is employed in the numerical analysis of the bore behavior over a beach of constant slope, for a variety of initial conditions. The numerical scheme employs finite difference counterparts of the nonlinear long wave equations and the bore conditions. An important result is that regardless of the initial conditions, the bore behavior eventually settles down to the functional dependence predicted by the approximate procedure.

The paper is a noteworthy contribution to a difficult nonlinear wave problem. It is particularly noteworthy in respect to the simplicity and apparent accuracy of the approximate analytical formulas. This is in spite of the fact that latter are based upon the rate of change of the bore parameters following at speed $u + \sqrt{gb}$, a value which is always greater than the bore speed U except at shore. This paradox is not resolved in the present paper.

R. O. Reid, USA

5904. Tolstoy, I., Guided waves in a fluid with continuously variable velocity overlying an elastic solid: Theory and experiment, *J. Acoust. Soc. Amer.* **32**, 1, 81-87, Jan. 1960.

Satisfactory agreement between theory and experiment has been secured for the propagation of very low frequency sound (10 and 20 cps) emitted by a point source in a thick sedimentary layer (607m) overlying a solid elastic basement. In the theory the sediment is treated as a fluid in which sound velocity varies with the depth, and the basement is represented by a solid elastic half-space. The wave equation has been integrated numerically on an electronic computer. The physical theory and, in particular, the coupling effects between sound waves and Stoneley or interface waves are discussed. R. C. Binder, USA

5905. Davids, N., and Kumar, S., Stress waves and scabbing in materials, Penn. State Univ., Engng. Res. Bull. B-79, 26 pp., Dec. 1959.

Scabbing is a type of damage produced in solid material by a pressure of high intensity suddenly applied at its boundary. Presented here is a brief introduction to the causes of scabbing, methods for prevention, and the use of scabbing data to develop knowledge of the dynamic properties of materials. The strain contour method for graphical analysis of elastoplastic wave propagation is described and applied to four types of cases. Recent literature is classified according to investigative approach (physical, mathematical, experimental, energy partition measurement) and briefly reviewed. From authors' summary

Fluid Machinery

(See also Revs. 5826, 5830, 5849, 5854, 5968, 5990, 5992, 5993, 6015, 6051)

5906. Liljestrand, W. E., Simplified approach to understanding the suction problems for reciprocating mud pumps, *ASME Trans.* **82** B (*J. Engng. Industry*), 2, 87-92, May, 1960.

This paper analyzes pump-suction and suction-piping characteristics showing responsibility areas of users and manufacturers. Empirical formulas and verifying test procedures are explained. This material should be used as a basis for preparation of standards on pump suction systems as used in the oil field. It will reduce pumping troubles and costs and permit increased pump output. From author's summary

5907. Kozmon, G., Vane-type compressed air motors (in Hungarian), *Gép* **11**, 5, 195-199, May 1959.

An analysis of a positive displacement, compressed air motor with sliding vanes and eccentric rotor is presented. Equations are derived for the thermodynamic work and losses; an empirical correction is used for friction losses. A geometrical correction factor accounts for the effect of vane thickness. Equation for the air consumption is given. A one metric horsepower motor is shown to have an over-all system efficiency of 13.9%.

G. Miskolczy, USA

5908. Polasek, J., Computation of flow through cascades of thin airfoils with high camber (in Czech), *Aplikace Matematiky* **3**, 5, 346–347, 1958.

The paper presents a simple method for computation of the irrotational incompressible flow through cascades of thin airfoils with high camber. The method is suitable for solving the indirect problem (the aerodynamic parameters of the cascade are known, the geometric parameters of the cascade are sought) and also for solving the direct problem (the geometric parameters of the cascade are known, the aerodynamic parameters of the cascade are sought).

The method is based on the work of Birnbaum and Glauert; the profiles of the cascade are replaced by lines with continuous distribution of vortices. The flow field past a profile in a cascade is considered as a nonhomogeneous flow field (induced by all remaining profiles) past a single profile. The induced nonhomogeneous flow field is not known a priori; the induced flow field is mainly dependent on sought parameters. The distribution of vortices and the velocity distribution are expanded into Glauert's series; in this manner both the problems (direct and indirect) are transferred to the problem of solving an infinite system of linear algebraic equations.

The method as presented in the paper is suitable for cascades with a pitch-chord ratio ≥ 0.5.

M. Ruzicka, Czechoslovakia

5909. Bikbulatov, Sh. Kh., The derivation of profile lattices for supersonic speeds (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Aviats. Tekhn.* no. 2, 86–92, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6172.

An approximate method of calculation is submitted for an arbitrary, plane, vortex-free supersonic flow, based on the adoption of approximate solutions of the equations for a plane, steady, adiabatic motion of a gas. The solutions are presented in the form of series in which the three first terms are conserved. With the aid of these series the derivation of the flow becomes possible provided one line of the current and the distribution of velocities along it are assigned. Examples of the calculation are given to demonstrate the accuracy of the results obtained by the proposed approximate method, among others the calculation for the flow-about of a blunt angle (Maier's flow). The comparison of calculated results with the results of the corresponding precise solutions shows that the error when calculating velocities λ by the approximate method does not exceed ~1.7%. Some general suggestions are given for the application of the proposed method to the derivation of supersonic lattices.

B. S. Dorogov

Courtesy Referativnyi Zhurnal, USSR

5910. Laskin, A. S., Investigation on the influence of the *R* number and the surface roughness on the efficiency of rows of turbine working blades (in Russian), *Nauchno-Tekhn. Inform. Byul. Leningrad Politekhn. In-ta* no. 3, 51–59, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6175.

Results are analyzed of an experimental investigation, carried out in an aerodynamic tunnel, of a single lattice of turbine profiles with assigned parameters, with Reynolds numbers R in the range of 7×10^4 to 2×10^5 and different degrees of roughness. A concept is advanced regarding the mean dynamic velocity in the inter-blade channel and the possibility is indicated of presenting the results in the form of a universal bond between the parameters characterizing the losses in the lattice. The existence of three types of flow is established ("the aerodynamic smooth" flow, the transition type and the developed roughness type) and corresponding curves are drawn. Emphasis is given to the point that, in order to correctly determine the losses in the lattice, it is necessary to have data for the roughness of the profiles.

N. A. Kolokol'tsov

Courtesy Referativnyi Zhurnal, USSR

5911. Den, G. N., Investigation of the aerodynamics of the section between inlet and outlet valves of compressor machines (in Russian), *Trudi Nevsk. Mashinostroits. Z-da* no. 1, 170–181, 1957 (1958); *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6203.

Results are given for the experimental investigations on the aerodynamics of bladeless and bladed diffusors of centrifugal compressors which were carried out at the Nevskii works. The investigations on the aerodynamics of the bladeless diffusors were carried out with two working wheels 305 mm in diameter, differing in the inlet angle ($\beta_1 = 32°$ and $45°$) with a peripheral velocity of $u_2 = 180$ to 190 m/sec. Examinations were made of the magnitude and direction of the velocities and of the field of full and static pressures in the diffusor. A brief description is given of the testing procedure and the apparatus used. It is shown that the field of velocities obtained at some distance from the wheel of a bladeless diffusor is not characteristic of the field of velocities at the outlet from the working wheel. For the investigation of the flow in a bladed diffusor and in the clearance between the working wheel and the bladed diffusor a model of the first section of a compressor type K-3250-41-1 was utilized; this consisted of a working wheel with a diameter $D = 305$ mm, a bladed diffusor with profiled blades and a spiral layout. Draining of the surface of the blades of the diffusor was carried out. It was established that when the coefficient of delivery exceeded the calculated value a break-away of the flow off the blades took place, the diffusor's work deteriorated sharply and reduced the efficiency of the compressor in all respects.

A short review is given of the studies dealing with investigations of the aerodynamics of centrifugal compressors.

B. S. Dorogov

Courtesy Referativnyi Zhurnal, USSR

5912. Fedorov, M. F., Calculation for the stage of an axial compressor, *Trudi Khar'kovsk. Politekhn. In-ta* **24,** 89–97, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1369.

An account is given of the known method of aerodynamic calculation for the portion of an axial compressor embracing the reaction between inlet and outlet valves through which steam passes, based on the employment of the generalized data on the blow-throughs of plane lattices and on a further generalization of this method by means of introducing and investigating the so-called special coefficients of the lifting force and the force of resistance of the profile in the lattice (work done by the author in 1950). Making use of these concepts the author proposes a relationship in the form of

$$\frac{\bar{H}_{th}^*}{\bar{c}_a} = f\left(\frac{\tau}{\bar{c}_a}, l^*\right)$$

where $\bar{H}_{th}^*$ is the coefficient of theoretical pressure, $c_a = c_a/u$, where c_a is the axial component of velocity, u the peripheral velocity, τ the kinematic degree of the reaction

$$l^* = \frac{1}{2}\frac{b}{t}\psi_y,$$

where b/t is the thickness of the lattice and ψ_y is the special coefficient of the lifting force. Continuing, by employing the assumption on the constancy of the outlet angle of flow from the lattice independent of the regime, author proposes the following relations between the coefficients of theoretical pressure for the calculated and the uncalculated regions

$$\bar{H}_{th} = 1 - (1 - \bar{H}_{th}^*)\frac{\bar{c}_a}{\bar{c}_a^*}$$

where the asterisks refer to the parameters on the calculated regime. With $\bar{H}_{th} < \bar{H}_{th}^*$ the calculation by this formula agrees well with experimental data. Generalized data are put forward for the

losses in the lattices which enable a transfer to be made from the coefficient of actual pressure both for the calculated as well as the uncalculated regimes. V. Kh. Abiants

Courtesy Referativnyi Zhurnal, USSR

5913. Podobuev, Yu. S., and Seleznev, K. P., A three-dimensional flow in the stage of an axial compressor with a reaction degree of 0.5 for Ω (in Russian), *Trudŭ Leningrad Politekhn. In-ta* no. 193, 157–167, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6201.

A calculation-investigation is carried out of the kinematic parameters determining the triangles of velocities of the stage of an axial compressor with constant pressure and a constant degree of reaction $\Omega = 0.5$ by the height of the blade and with an approximate constant axial velocity by the height of the blade. The investigation was made for an incompressible liquid with the use of a simplified equation for radial equilibrium, taking into account only the pressure gradient from the peripheral constituent of the velocity of the flow. It is assumed that the body and the bush of the compressor are in the form of a cylinder. Examples are furnished of the calculations for the stages of the given type and a comparison is given of the results of the calculations of these stages with the stage designed in accordance with the principle of constant circulation. B. S. Dorogov

Courtesy Referativnyi Zhurnal, USSR

5914. Wood, M. D., Horlock, J. H., and Armstrong, E. K., Experimental investigation of the stalled flow of a single-stage axial flow compressor, *Aero. Quart.* **11,** 2, 159–170, May 1960.

It is shown experimentally that variation of axial spacing between neighboring blade rows can alter the stall characteristics of a compressor stage. The stall cell patterns of this compressor stage are described in detail and changes of slope in stage temperature and pressure rise characteristics are explained in terms of stall propagation. Strain-gage tests on stator blades are used to indicate the possibility of large dynamic stresses occurring when the stall cell frequency is equal to the blade natural bending frequency. From authors' summary

5915. Hammitt, A. G., and Bogdonoff, S. M., Radial equilibrium in supersonic compressors, *ASME Trans.* **81** D (*J. Basic Engng.*), 4, 552–558, Dec. 1959.

The flow in rotors and stators of compressor with supersonic inlet velocities is considered. The equations are established which relate the states before the shocks with the states after the shock, assuming that no radial acceleration exists. Qualitatively it is found that with almost arbitrary upstream conditions, oblique shocks will flow on concentric cylinders as a possibility but the shock angle is a function of the radius as determined by the existing upstream conditions. Results of such calculations for assumed upstream conditions are given in graphical form.

Reviewer finds that the presented calculations are qualitatively quite instructive, but do not apply to supersonic impellers which are designed with strong radial accelerations within the impeller. H. P. Eichenberger, USA

5916. Agostinelli, A., Nobles, D., and Mockridge, C. R., An experimental investigation of radial thrust in centrifugal pumps, *ASME Trans.* **82** A (*J. Engng. Power*), 2, 120–126, Apr. 1960.

An experimental investigation has been conducted to determine the magnitudes and directions of the unbalanced radial forces on centrifugal pump impellers. The work covers single volutes for a wide specific speed range, double volutes, concentric casings, and modifications of the concentric casing. The results are presented in graphical form and are discussed.

A method, making use of strain gages, was devised for determining the magnitudes and directions of the resultant radial forces and is described. From authors' summary

5917. Kramer, J. J., Osborn, W. M., and Hamrick, J. T., Design and test of mixed-flow and centrifugal impellers, *ASME Trans.* **82** A (*J. Engng: Power*), 2, 127–134, Apr. 1960.

Procedures for designing the hub-shroud contour and the blade shape of mixed-flow and centrifugal impellers are presented and evaluated in terms of experimental results obtained for impellers designed by these methods. The experimental results in general indicate that these design procedures are reliable. Additional experimental results with varying boundary-layer allowance and some vaned diffuser test results are presented.

From authors' summary

5918. Tonks, R. J., and Smith, A. G., A theory for flow with axial symmetry in centrifugal impellers, *Aero. Quart.* **11,** 1, 22–40, Feb. 1960.

A theory of incompressible inviscid flow with axial symmetry through the impeller of a centrifugal compressor is presented. The theory is applicable to blade shapes which are not composed of radial fibers as well as radial blades. The theory is applied to compute the flow through two impellers. For each design the experimental axial velocity distribution at the impeller eye is in good agreement with that computed numerically from the theory except near the shroud. The method will be useful for design of centrifugal compressors. Y. Senoo, USA

5919. Faschallegg, E., Contribution to the shape determination of blades in centrifugal compressors of high revolution (in German), *Öst. Ingenieur Z.* **2,** 10, 368–376, Oct. 1959.

An investigation is made of the extent to which the shaping of the blades and the behavior of a mixed-flow centrifugal compressor are influenced by the application of a two-dimensional calculation procedure in comparison to the common one-dimensional procedure. For this purpose a rotor is designed according to the one-dimensional theory with linear deceleration of the relative velocity along the medium meridian streamline and further, a comparable rotor with due consideration being given to the equilibrium of flow normal to the meridian streamlines. The latter permits a better adaptation of the blade shape across the duct area to the desired flow condition. The measured characteristics result in a remarkable improvement in efficiency of the two-dimensional design. Pressure distribution and velocity measurements check satisfactorily with the two-dimensional calculation.

N. Scholz, Germany

5920. Banerjee, D., Some aspects of cascade flow study for compressor blade design, *J. Sci. Engng. Res., India* **3,** 2, 291–304, July 1959.

Paper presents a critical review of the work done on flow in two-dimensional cascades of blades with particular reference to compressor blade design. The scope of the paper has been restricted to low-speed cascade study although reference has been made of high subsonic cascade flow also. The use of theoretical method of blade cascade analysis is also discussed. At the end of the paper some special problems in cascade flow study, such as effect of boundary layer, Reynolds number, Mach number and secondary flow, are briefly discussed. The work done at the Bengal Engineering College is discussed and suggestions are made for some future research in the field.

From author's summary

5921. Shimosaka, M., and Yamazaki, S., Research on the characteristics of a regenerative pump (1st report: Influences of flow channel and impeller), *Bull. JSME* **3,** 10, 185–190, May 1960.

Authors carried out experiments on a regenerative pump systematically, changing the dimensions of flow channels, impellers and clearances. And they propose a "characteristic dimension of flow channel" for a parameter.

Then the following results are obtained through these experiments.

(1) The influence of the clearances on the pump performance depends on the characteristic dimension of flow channel. The allowable clearance is decided by the value of the characteristic dimension of flow channel.

(2) The pump efficiency is high in the adequate range of impeller dimension and characteristic dimension of flow channel.

(3) The influence of number of vanes on the pump performance depends on the width ratio of vane.

(4) The pump performance depends on the combinations of characteristic dimension of flow channel, width ratio, thickness and length of vane.

(5) The upper and lower limits of characteristic dimension of flow channel are fixed by the values of clearance and dimension of impeller. From authors' summary

5922. Shimosaka, M., Research on the characteristics of a regenerative pump (2nd report: Theoretical research on the performance), *Bull. JSME* **3,** 10, 191–199, May 1960.

According to the author's preceding research on a regenerative pump [see preceding review], in which the flow channel and the impeller dimensions were widely changed, the pump performance is influenced by their relations. Then it is obvious that the analysis of performance can not be considered without taking these relations into account, when they vary with each other.

The author's analysis considers their effects on the performance. He shows that the theoretical equations for performance are available for practical purposes.

From author's summary

Flow and Flight Test Techniques and Measurements

(See also Revs. 5572, 5597, 5810, 5868, 5878, 5882, 6091, 6128)

5923. Thibessard, G., On the expansion number when measuring discharge with standard orifices (in German), *Brennstoff-Wärme-Kraft* **12,** 3, 97–101, Mar. 1960.

Three new empirical equations for any chosen adiabatic exponents are compared with the empirical equation used in American discharge measurement standards for the expansion number of orifices. One of the former results in much more exact expansion numbers, i.e. with a maximum uncertainty of $\pm 0.25\%$, as standardised in the VDI discharge measurement standards.

From author's summary

5924. Systematic errors of discharge measurements from unsuited installations of the measuring orifice (in German), *Brennstoff-Wärme-Kraft* **12,** 3, p. 113, Mar. 1960.

5925. Burke, O., Comments on the expansion number of standard nozzles (in German), *Brennstoff-Wärme-Kraft* **12,** 3, p. 102, Mar. 1960.

5926. Kestin, J., and Leidenfrost, W., Design and operation of an oscillating-body viscometer for gases at high pressures, AFOSR TN 60-375 (Brown Univ., Div. Engng. TR 12), 79 pp., Mar. 1960.

Report describes in detail the design and the operating experience obtained with various types of oscillating-body viscometers of high precision.

Satisfactory results could be obtained only with an oscillating system consisting of a flat circular disk oscillating between two flat plates a small distance apart.

Oscillating systems involving a free disk or a free sphere suffer from instabilities and do not yield satisfactory reproducibility. Oscillating systems involving concentric spheres with small gaps suffer from a large systematic error whose origin was not fully explored. From authors' summary

5927. Charron, F., Ballistic viscosimetry (in French), Publ. Scient. Tech. Min. Air, France no. 350, 15 pp., 1959.

Under the assumption of quasi-steady Hagen-Poiseuille motion it is shown that the total displacement of piston impulsively loaded with fixed initial momentum is a simple function of viscosity. The piston is at one end of a capillary tube filled with the liquid whose viscosity is to be measured. Experiments with a variety of liquids indicate that the device is rough but rapid. No attempt is made to justify the assumption of quasi-steady motion.

S. Corrsin, USA

5928. Tolhurst, W. H., Jr., Kelly, M. W., and Greif, R. K., Full-scale wind-tunnel investigation of the effects of a target-type thrust reverser on the low-speed aerodynamic characteristics of a single-engine jet airplane, NASA TN D-72, 42 pp., Sept. 1959.

Full-scale tests were conducted in the Ames 40-by-80-foot wind tunnel on a YF-86D airplane equipped with a J-34 turbojet engine and a thrust reverser. Major effect of reverser operation on airplane stability was a large nose-down pitching moment due to altered downwash pattern in vicinity of horizontal tail. Other effects were increased skin temperature and induced buffeting loads.

T. R. Goodman, USA

5929. Gainer, T. G., Subsonic wind-tunnel investigation of the aerodynamic effects of pivoting a low-aspect-ratio wing to large yaw angles with respect to the fuselage to increase lift-drag ratio, NASA TN D-225, 20 pp., Mar. 1960.

Three wing planforms were tested—a delta, a diamond, and a rectangle—with the wing pivoted at angles between the wing and fuselage center lines from 0° to 109°. The investigation was made in the Langley high-speed 7- by 10-ft tunnel at a Mach number of about 0.4 and a Reynolds number of about 3×10^6. Lift, drag, pitching-moment, and rolling-moment data were obtained through an angle-of-attack range from -4° to about 24°.

From author's summary

5930. Saito, H., On the aileron buzz in the transonic flow, Aero. Res. Inst., Tokyo University, Rep. 346, 109–147, July 1959.

An ambitious work about a transonic problem important for airplane designers. If some of the conclusions drawn are correct, the problem has been enriched. However, reviewer finds the conclusions drawn to be too extensive, as the dynamic characteristic of the test equipment is poorly known. The report is unnecessarily verbose, the reproduction of the photos is bad, and a disposition of the symbols and definitions used is lacking.

K. Fristedt, Sweden

5931. Comte-Bellot, Genevieve, Coefficient of flattening of the longitudinal speed fluctuations of fluid flow in a two-dimensional tunnel with parallel walls (in French), *C. R. Acad. Sci., Paris* **249,** 22, 2270–2272, Nov. 1959.

5932. Blanchard, W. S., Jr., and Hoffman, S., Effects of nose corner radii, afterbody section deflections, and a drogue chute on subsonic motions of manned-satellite models in reentry configuration, NASA TN D-223, 16 pp., Mar. 1960.

Small models of manned orbital vehicles in the reentry configuration were tested with various body changes in the Langley 20-ft free-spinning tunnel. The basic shape with various nose corner radii experienced large steady-state oscillations. Large reductions in the amplitude of the oscillations were obtained by either a small drogue chute or opening the afterbody in three or four sections. The models with large corner radii and opened afterbodies had virtually no steady-state oscillations.

From authors' summary

5933. Haines, A. B., and Jones, J. C. M., The centre-line Mach-number distributions and auxiliary-suction requirements for the A. R. A. 9-ft × 8-ft transonic wind tunnel, Aero. Res. Counc. Lond. Rep. Mem. 3140, 51 pp., 1960.

5934. Tamaki, F., and Kim, C.-S., Flash X-ray radiography for the density measurement in a hypersonic air flow, *J. Phys. Soc. Japan* **14,** 5, 664–669, May 1959.

Soft x-ray radiograph method was developed and used to measure density distribution between detached shock wave and a circular cylinder at a Mach number of 5.5 and free-stream density of 0.1 atmosphere. Although results indicate x-ray absorption methods are possible, reviewer believes that a great deal of improvement and refinement of equipment such as that described is necessary before any significant utility can be realized.

R. L. Trimpi, USA

5935. Stalker, R. J., Isentropic compression of shock tube driver gas, *ARS J.* **30,** 6, p. 564 (Tech. Notes), June 1960.

5936. Voepel, H., Free-flight testing in high velocity research (in German), *Z. Flugwiss.* **7,** 4, 85–102, Apr. 1959.

An outline is given of free-flight techniques in Great Britain covering both the required research facilities and the test methods applied. Special attention has been paid to the flight-mechanical evaluation methods of the results for both longitudinal and lateral motion of the model; cross coupling effects are also taken into account. The article thus gives a concise survey of the possibilities and limitations in determining the aerodynamic coefficients and derivatives. For many interesting details reference is made to the literature.

J. Buhrman, Holland

5937. L'Hermitte, R., Measuring the speed of falling particles by means of radar (in French), *C. R. Acad. Sci., Paris* **249,** 19, 1923–1925, Nov. 1959.

Thermodynamics

(See also Revs. 5626, 5843, 5866, 5907, 5984, 5996, 6006, 6053, 6054, 6071)

Book—5938. Flugge, S., edited by, Encyclopedia of physics, Vol. III/2, Principles of thermodynamics [Handbuch der Physik, Band III/2, Prinzipien der Thermodynamik und Statistik], Berlin, Springer-Verlag, 1959, vii + 678 pp. $38.64.

This volume of the famous Encyclopedia of Physics edited by S. Flügge is devoted to the exposition of the principles of thermodynamics, including irreversible thermodynamics, and statistical mechanics. The articles are devoted mainly to the discussion of general principles; applications to specific systems are treated in other volumes of the "Handbuch."

The book opens with an article of 112 pages entitled "Thermodynamics, classical and statistical" by Professor E. A. Guggenheim, setting out the principles of classical thermostatics and their statistical interpretation. Readers familiar with Professor Guggenheim's textbook ["Thermodynamics," Amsterdam, 1950] will find in this survey the same concise style, with careful definitions and derivations characteristic of the earlier work. The basic relations are developed in 22 pages, the remainder of the article being devoted to applications and the principles of equilibrium statistical mechanics. The article contains a short but most interesting chronological historical survey of the main advances in classical thermodynamics and statistical thermodynamics.

The article of G. Falk and H. Jung entitled "Axiomatik der Thermodynamik" is unique in the volume, being not so much a review of attempts to formulate thermodynamics on an axiomatic basis as an original contribution to the subject. It is impossible to summarize the argument in a brief review other than to state that it is based upon, but significantly different from, the work of Carathéodóry.

The largest, and in many aspects the most valuable, article in the volume is contributed by A. Münster and entitled "Prinzipien der Statistischen Thermodynamik." It is distinguished by clarity of exposition illuminating the conceptual and mathematical difficulties of the subject, as well as a full discussion of modern developments found heretofore only in the periodical literature. The article is divided into three main chapters: classical statistical mechanics, quantum statistics, and statistical foundations of thermodynamics. In recent years there has been a very strong revival of interest in problems of statistical physics. In the reviewer's opinion, Dr. Münster's contribution will serve as the classic introduction to the subject for some time to come.

The fourth article in the volume, "Thermodynamik der Irriversiblen Prozesse" by J. Meixner and H. G. Reik, summarizes our knowledge of the application of macroscopic thermodynamic methods of nonequilibrium processes. The most interesting applications of the theory are to continuous systems, and it is the great merit of this article to devote major attention to these, referring the reader to earlier works (e.g., deGroot and Prigogine) for other aspects of the subject. Readers of AMR working on continuum mechanics will be particularly interested in the emphasis on the field formulation of irreversible thermodynamics emphasized in this article. There is a concluding section (rather brief) on the statistical mechanical theory of irreversible processes.

The object of the concluding article of the book, "Probability and stochastic processes" by A. Ramakrishnan, is, in the author's words, to present the mathematical theory of stochastic processes "in a serviceable form which can be applied to physical problems by a physicist." It is the author's thesis that the treatment of stochastic theory as a branch of measure theory by mathematicians has tended to repel those who might otherwise apply the theory to physical problems. The article is divided into two main sections; the first dealing with the exposition of the relevant mathematical theory in a form designed to lead most rapidly to usable relations and the second connecting the mathematical theory to physical problems with examples of applications. It is not surprising that the author's intention of bridging the gap between the mathematical formalism and physical problems is only partially fulfilled. The value of the article lies in bringing to the reader's attention a series of problems requiring the notion of a random variable and its calculus, and directing him to further study through a brief but carefully chosen bibliography.

In an era of explosive publication in the physical sciences, encyclopedic review articles assume particular importance. The authors, editor, and publisher are to be congratulated on preparing a reference volume which will afford the student or research worker a measure of high ground on which he may stand—at least temporarily.

L. M. Grossman, USA

Book—5939. Prigogine, I., edited by, Advances in chemical physics, Vol. 2, New York, Interscience Publishers, Inc., 1959, ix + 412 pp. $11.50.

This book contains 9 chapters by different authors on the topics of chemical physics of which the following two chapters are related to topics in the fields covered by AMR: "Inter- and intramolecular forces and molecular polarizability" by Kenneth S. Pitzer and "Thermodynamics of metallic solutions" by R. A. Oriani.

Ed.

5940. Mokadam, R. G., Joule-Thomson effect in discontinuous system, Proc. 3rd Congr. Theor. Appl. Mech., Bangalore, India; Indian Soc. Theor. Appl. Mech., Indian Inst. Technol., Kharagpur; 1957, 315–322.

In the analysis of discontinuous systems, De Groot has indicated only two important effects, namely the thermomechanical effect and the thermomolecular pressure difference. According to De

Groot the magnitude of these effects can be obtained from kinetic considerations. In present paper, author has carried the above analysis further to include the Joule-Thomson effect and has shown that the magnitude and sign of the thermomechanical effect and thermomolecular pressure difference depend upon the Joule-Thomson coefficient.

From author's summary by P. E. Kriezis, Greece

5941. Bloomer, O. T., and Peck, R. E., Modified law of corresponding states for gases, *AIChE J.* **6,** 2, 240–245, June 1960.

A new correlation is presented for predicting the pressure-volume-temperature relations of nonpolar (and slightly polar) gases. The correlation modifies the law of corresponding states in which a third parameter, the slope of the pseudocritical isometric in dimensionless form, is introduced. This parameter is introduced in a simple manner by multiplying the reduced pressure and temperature of the gas by a factor which can be easily calculated or read from a graph. This gives the corrected reduced pressure and temperature which can then be used with a generalized compressibility factor chart in place of the true values. The correlation is accurate for densities up to about 1.2 times the critical density.

A detailed comparison of the method with data on twelve pure gases showed that by introducing this parameter into the law of corresponding states the average error was decreased from 1.598 to 0.320%. The parameter S can readily be determined from experimental PVT data, and only one isotherm is required. S is related to the vapor-pressure curve for a substance as characterized by the critical pressure and the ratio of the critical temperature to the normal boiling temperature, and a simple method is proposed for predicting S when no experimental data are available.

A new set of generalized compressibility factor and fugacity to pressure ratio charts is presented for use with the proposed correlation. A method is also presented for determining the thermodynamic functions. From authors' summary

5942. Vasserman, A. A., and Kazavchinsky, Y. Z., The equation of state for air (in Russian), *Inzhenerno-Fizicheskii Zh.* **3,** 4, 81–84, Apr. 1960.

An equation of state for air is obtained; this equation is applicable for a range of densities from zero to two critical values for a wide range of temperature changes. A comparison of calculation results with the majority of all existing experimental data of compressibility is given.

The obtained equation of state reflects the existing reliable experimental PVT-data for air with high precision, and it can be used for calculation of calorific values.

From authors' summary

5943. Tkachenko, E. A., Pressure-density-temperature relationship of liquid O, *ARS J.* **30,** 6, 566–568 (Tech. Notes), June 1960.

Two methods, one based on thermodynamics, the other on a generalized equation of state, are employed in conjunction to calculate the pressure-density-temperature relationship of liquid oxygen in the temperature range of 110 to 210 R, and in the pressure range of saturation conditions to 2500 psia. Since no compressibility data for liquid oxygen are available at temperatures higher than 160 R, the results of this investigation should be of special use in rocket engine applications, where the temperature interval 160 to 210 R is of greatest interest. The pressure-density-temperature relationship of liquid oxygen is presented in tabular form, whereas the coefficient of isothermal compressibility is shown graphically, and is compared with previous calculated values.

From author's summary

5944. Mundo, K.-J., Mixture heats at high pressures and temperatures, especially of methylamine-water mixtures (in German), *Forsch. Geb. Ing.-Wes.* **26,** 1, 8–18, 1960.

A test rig was developed which allows for measuring the mixture heat of liquid binary systems at temperatures and pressures as used in power plants. In this apparatus, which works with flowing components, the heating-up of the mixture represents a measure of the heat produced. It is thus possible to determine the total heat of mixing from only two temperature differences and the concentration of the mixture. The measurement does not require reaching the steady state. After testing the rig and the accuracy of measurement to be expected by means of a known binary mixture the system methylamine-water was investigated and an enthalpy-versus-concentration diagram of the liquid phase established for this system. From author's summary

5945. Filippov, L. P., and Pashenkova, I. G., Measurement of the coefficient of thermal conductivity of liquids (in Russian), *Inzh.-Fiz. Zh.* **1,** 8, 4–88, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6599.

The method and the apparatus are described which make possible the measurement of the coefficient of thermal conductivity of liquids. The liquid under investigation is placed between two plane surfaces, the temperature of which changes with time in conformity with the linear principle. The coefficient of thermal conductivity is determined by measured values for the difference of temperature at two points in the liquid. Results are given for the measurement of the coefficient of thermal conductivity at 34°. The accuracy of the results is estimated at between 4 to 5%.

K. K. Vasilevskii

Courtesy Referativnyi Zhurnal, USSR

5946. Thomsen, J. S., Thermodynamics of an irreversible quasi-static process, *Amer. J. Phys.* **28,** 2, 119–122, Feb. 1960.

Paper gives a mathematical analysis of a dissipative process (mechanical friction) for which the rate of entropy production vanishes linearly with the process rate, rather than quadratically as in viscous flow, heat conduction and diffusion. This means that a quasi-static path does not, to the first order, connect equilibrium states (zero entropy production rate) and so the usual assumption of equivalence of a quasi-static and a reversible process is invalid. Such a process can be described uniquely in terms of the external quantities (temperature, force and displacement and the heat balance) only if an appropriate initial condition is stated.

The author has elected to describe the behavior of a system subject to sliding friction and consisting of a gas-containing cylinder with a piston by introducing the virtual concept of reversible force, F_r. He shows that the thermodynamic path can be uniquely defined for any operating temperature provided an initial condition is stated of the form $F_r(X, T_0)$, where X is the displacement and T_0 is any particular temperature. Since this condition can only be determined by measurement of certain internal parameters (e.g. pressure) it is demonstrated that the instantaneous state of a working fluid in a quasi-static irreversible process cannot be defined by external measurements alone.

J. S. Kirkaldy, Canada

5947. Justi, E., Physical principles of thermoelectric cooling and progress in the development of suitable materials (in German), *Kältetechnik* **12,** 5, 126–136, May 1960.

The fundamentals of thermoelectric cooling as well as advances in technology of the applied materials are discussed in a way understandable to refrigerating engineers who are not familiar with solid-state physics. Therefore physical details and economical views are only briefly mentioned. At the end of the paper, author reports on his own experiments with the system $Zn_xCd_{1-x}Sb$. Finally, prospects of a further increase of the thermoelectric efficiency are discussed. From author's summary

5948. Hanlein, W., Technological problems in the application of the Peltier-effect (in German), *Kältetechnik* **12,** 5, 137–144, May 1960.

The present state of knowledge gives the possibility of technical applications of the Peltier-effect, but to overcome the diffi-

culties encountered the technological problems must be thoroughly studied. The advantages offered by the application of the Peltier-effect are: Large areas may be uniformly cooled and low temperatures may be obtained with small units.

From author's summary

Book—5949. Andersen, S. A., Automatic refrigeration, London, MacLaren & Sons Ltd., 1959, xv + 649 pp. + diagrams. DKr 85.

This book, by Prof. Andersen of the Technical Univ. of Denmark, was written to be published on the 25th anniversary of the founding of the Danfoss Co., Nordborg, Denmark. Contents emphasize the fundamentals of refrigeration thermodynamics, heat transfer, and automatic control devices and systems. Material and presentation, with selective emphasis to suit, will appeal to practicing engineers desiring an introductory reference book, to technical school students who wish a survey text which does not require going deeply into the analytical material in the last half of the book, and to engineering college students seeking a good first-course book with many leads to contemporary problems.

Chapters 1 through 5 emphasize techniques and applications. Psychrometric processes are well introduced, using both the Mollier and the Carrier charts. Refrigeration principles, equipment features, and operations are clearly presented, and the descriptive material on automatic controls is excellent—indeed, color signatures are strikingly employed in detailed sectional views of typical devices. Complete refrigeration plants of all sorts are described, including dry ice and liquid gas. Drawings and photographs are very good.

Chapters 6 and 7, comprising 276 pages, present calculation procedures, illustrative examples, tables and charts. Material is in the nature of a survey rather than an advanced analytical treatment, but everything technical needed for the preliminary design and specification of workable plants is covered. Sections cover steady and unsteady heat transfer, water vapor transfer, heat exchangers, compressors (including staging and liquid injection), absorption and steam-jet cycles, fluid flow, pumps, fans, ice making and plant layout. The tabular data are good and the multicolor charts are nicely done.

Further commendable features include the presentation of three sets of units,—British, technical metric, and MKS—and pages with very wide inner margins which are used for captions, sketches, and reader's notes. Combined with usual supplementary classroom material and selected excursions into more advanced topics, college teachers should consider this carefully for a first-course text.

H. B. Nottage, USA

5950. Horiguchi, Y., Funayama, T., and Nakanishi, T., Studies on temperature-indicating paints, Part I: Heat stability of iodomercurate pigmented reversible temperature-indicating paints, Inst. Phys. Chem. Res., Scient. Pap., Tokyo. **53,** Pap. 1526, Dec. 1959.

Stability against heat of heat-sensitive iodomercurates and temperature-indicating paints pigmented with the said iodomercurates is examined. Poor heat stability of iodomercurate-pigmented paints is attributable to thermal decomposition of iodomercurate at moderately high temperatures. Improvement in the thermal resistance of iodomercurate can be made if incorporated with vehicles, among which the most efficient is the varnish based on copolymer resin of methyl methacrylate-vinyl acetate. There is little relation between the heat-resisting property of the vehicle employed and the heat stability of iodomercurate-pigmented paints.

From authors' summary

Heat and Mass Transfer

(See also Revs. 5554, 5560, 5612, 5660, 5755, 5865, 5866, 5939, 5945, 5947, 5948, 5949, 5950, 6002, 6007, 6030, 6032, 6053, 6054, 6069, 6073)

5951. Citron, S. J., A note on the relation of Biot's method in heat conduction to a least-squares procedure, *J. Aero/Space Sci.* **27,** 4, 317–318 (Readers' Forum), Apr. 1960.

Author shows that a relation exists between Biot's variational method in heat conduction and the method of least squares. Author applies the method to study the temperature in the problem of the melting of a semi-infinite body under constant heat input. At the start of melting the temperature is known exactly and therefore a comparison between the exact solution and several approximations obtained by Biot's method can be made. A graph exhibits a remarkable divergence.

G. Sestini, Italy

5952. Demetriades, A., Heat conduction in a circular cylinder rotating with its axis normal to the direction of flight, *ARS J.* **29,** 9, 653–655, Sept. 1959.

Author determines the temperature distribution law in a circular cylinder in an hypersonic stream normal to the axis; it is assumed that the cylinder is rotating with constant angular velocity, starting from a given moment. Author further assumes a distribution of the heat-transfer rate around the cylinder circumference given by a cosine function. The law obtained shows how the temperature depends on the parameter $\frac{D}{\omega R^2}$ (D = thermal diffusivity; ω angular velocity; R cylinder radius). This law shows that for small values of this parameter the surface temperature in the stagnation point may be highly reduced by the rotation. Reviewer believes that the assumption made on the variation of the heat-transfer rate around the circunference may be correct for the upstream half part of the cylinder but not for the downstream half part.

C. Ferrari, Italy

5953. Concer, D. B., Heat flow towards a moving cavity, *Quart. J. Mech. Appl. Math.* **12,** 2, 222–231, May 1959.

Using analytical methods, author determines temperature distribution in an infinite homogeneous medium with a cavity moving through it. Part I describes solution for the case when cavity is an infinite cylinder moving at velocity U perpendicular to cylinder axis. In part II, the cavity is an infinite elliptical cylinder moving in direction of major axis. Important relationship derived is expression for rate of heat flow into cavity as function of velocity U, cavity dimensions, surface temperature of cavity, and temperature and properties of medium. Solution for elliptical case reduces to that for circular cylinder when major and minor axes become equal. Problem has application in calculating heat flow into deep mines where the stope moves through the earth at a known velocity.

J. G. Knudsen, USA

5954. Novitskii, B. F., Calculations for the directed changes of temperature of an unbounded plate (in Russian), *Trudi Leningrad Tekhnol. In-ta Pishch. Prom-sti* **14,** 235–241, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6662.

The problem on the determination of the temperature of an unbounded plate is investigated in conditions where the temperature of the surrounding medium changes in relation to time τ along an arbitrarily assigned curve $f(\tau)$. The initial temperature in the plate is assumed to be constant and equal to the initial temperature of the medium. It is proposed to divide the duration of the process into intervals τ in such a fashion that in each of these subdivisions the corresponding part of the curve $f(\tau)$ could be replaced with the required exactness of a straight line. That being done, the problem can then be solved for each of the intervals, in every one of which the temperature of the medium will be a linear function of time. A formula is given for the calculation of the temperature in some section of the plate at a moment of time corresponding to the end of an interval τ_i; this is accomplished on the basis of the known solution of the problem in an unbounded plate where heat exchange is taking place with the medium on the boundary, the temperature of which is a linear function of time. In this manner,

the sought curve to express the relationship of the temperature to time in some section of the plate can be represented graphically in the form of a broken curve. With the assistance of the same formula the converse problem is solved, namely a curve $f(\tau)$ is sought according to which the temperature of the medium will vary to obtain the assigned relationship of changes of temperature of the plate. For the purpose of illustrating the technical detail of the calculations an examination is made of a numerical example.

I. N. Danilova

Courtesy Referativnyi Zhurnal, USSR

5955. Smirnov, M. S., Asymmetric heating of a plate when an internal source of heat is in operation (in Russian), *Sb. Rabot. Vses. Zaochn. In-ta Pishch. Prom-sti* no. 3, 49–53, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6663.

The equation is solved for the heat conductivity of a plate with distributed internal sources of heat, the intensivity of which vary with the thickness of the plate and with time; the method used for the solution was that of finite Fourier integral conversions. The surfaces of the plate are in contact with media, the temperatures of which are known functions of time. The solution is obtained in the form of a series.

M. I. Gusein Zade

Courtesy Referativnyi Zhurnal, USSR

5956. Molchanov, E. I., A method of approximating the calculation of temperature fields in cooled disc rotors of gas turbines (in Russian), *Inzhenerno-Fizicheskii Zh.* **3,** 4, 99–102, Apr. 1960.

The temperature field in disks of gas pipes cooled from the ends is calculated according to approximate formulas, and the coefficients in them are determined according to graphs constructed on the basis of an analysis of solutions of 228 problems.

For a calculation of thermal tension an exponential dependence of distribution of temperature along the radius of a disk is taken; the coefficient of the exponent for a relative radius is determined according to graphs.

With the proposed method, radial temperature drop, arising when the apparatus is started and in established heat conditions, can be determined quickly and with sufficient accuracy, and maximum temperature for the latter case can be assessed.

From author's summary

5957. Molchanov, E. I., The investigation of temperature fields arising in the cooled down rotor of a gas turbine (in Russian), *Teploenergetika* no. 4, 53–56, 1960.

The calculation results of temperature field which arise in the rotor of a gas turbine at various types of cooling are given, showing the effect produced by heat-transfer coefficients and by the temperature of agent supplied for cooling the disk upon the value of radial temperature drop during the heating up and at the steady temperature conditions.

From author's summary

5958. Asawo, H., An approximate solution of oil-cooling pipe, *Bull. JSME* **2,** 7, 433–439, Aug. 1959.

Integral method with two thicknesses and fourth-degree polynomials is applied to determine heat transfer in fully-developed laminar pipe flow with variable viscosity. Results are compared to experimental data of same author and shown to be in good agreement.

P. A. Libby, USA

5959. Asawo, H., Experiment on the heat-transfer of oil-cooling pipe, *Bull. JSME* **2,** 7, 429–432, Aug. 1959.

Experiments were carried out on laminar heat transfer in fully-developed pipe flow with two types of oils. Temperatures were in the range 40–80 °C. Results are correlated in terms of a mean temperature parameter and of Graetz number.

P. A. Libby, USA

5960. Randall, I. E., and Sesonske, A., Effect of a volume heat source on free-convection heat transfer, *AICHE J.* **5,** 2, 150–154, June 1959.

Authors attempt to model cooling by a horizontal cylinder of an extensive region of fluid with a uniform distribution of heat sources, by investigating the thermal boundary layer on a vertical cooled plate with a uniform distribution of sources *throughout the boundary layer only*. Karman-Pohlhausen techniques are used to obtain solution as power series in parameter representing source strength, and authors predict increased heat-transfer coefficient due to thinning of boundary layer. Results are extended to horizontal cylinders.

Reviewer finds problem badly conceived and paper poorly written. Decision to model extensive distribution of heat generation by neglecting all heat sources outside boundary layer is justified only by reference to experiments the character of which is not even suggested here, and by fact that authors could not handle more realistic formulation. No discussion is given of physical significance of results, but in view of fact that heat sources do not move with fluid this is probably slight. Results follow as consequence of unreal temperature excess in boundary layer.

B. R. Morton, England

5961. Chauvin, L. T., and Buglia, J. J., Measurement of aerodynamic heat transfer to a deflected trailing-edge flap on a delta fin in free flight at Mach numbers from 1.5 to 2.6, NASA TN D–250, 18 pp., June 1960.

Heat-transfer measurements on the trailing-edge flap of a 60 ° clipped delta fin have been made at small angles of attack for deflections of 10 ° amd 20 °. Flight Reynolds number was 11×10^6 to 18×10^6 based on wing mean aerodynamic chord of 1.48 feet. The measured heat-transfer coefficient was 2.5 times that of the fin measurements for the windward side of the 20 ° deflected control and about one-third for the leeward side. The data for the 10° control were 1.75 times those of the fin for the windward side and 0.6 for those of the fin for the leeward side. Theory for a turbulent boundary layer was in good agreement with the test results.

From authors' summary

5962. English, R. D., and Carter, H. S., Variation in heat transfer during transient heating of a hemisphere at a Mach number of 2, NASA TN D–399, 26 pp., June 1960.

Tests were made at various stagnation temperatures to determine the variation of Stanton number with the ratio of wall temperature to total temperature. For laminar flow on the 5-inch-diameter hemisphere, the Stanton number remained essentially constant as the ratio of wall temperature to total temperature increased. However, for fully established turbulent flow, the Stanton number at some stations decreased on the order of 50% as the ratio of wall temperature to total temperature increased.

From authors' summary

5963. Fujimoto, T., and Takao, K., Heat transfer in the rarefied gases, Parts 1 and 2, *Bull. JSME* **2,** 6, 197–204; 204–209, May 1959.

Author treats the problem of heat transfer between two parallel plates in rarefied gases. Owing to the fact that distribution function is discontinuous between incident and reflecting molecules, different distribution functions for both on-coming and reflecting molecules have to be adopted in order to satisfy the boundary conditions at the wall. By using such a distribution function, the temperature distribution between the plates is derived.

In part II, experiments for measuring the heat-transfer coefficient are described.

Y. H. Kuo, China

5964. Glansdorff, P., Deduction of the force of mutual friction in a gaseous "two-fluid" model (in French), *Acad. Roy. Belgique, Bull. Cl. Sci.* (5) **45,** 6, 575–582, 1959.

It is assumed that the collisional exchange of momentum in a binary gas mixture is almost entirely restricted to molecules of the same kind whereas the exchange between the two components is a rare event. In this case both components may be in thermal equilibrium but have different temperatures and different macroscopic velocities. Evaluating the contribution to the Boltzmann equation of collisions between molecules of different kind, the mean rate of momentum transfer from one component to the other is derived. As this rate is found to be proportional to the difference in macroscopic velocities, a coefficient of mutual friction can be defined in analogy to the corresponding quantity appropriate to liquid helium. It is asserted that diffusion in the above mixture is of an anomalous kind.

Reviewer recognizes the virtual significance of a two-fluid model which is derived from classical concepts without any appeal to quantum effects. It would, however, be necessary to show that the properties of this mixture are compatible with any known type of intermolecular forces. R. Eisenschitz, England

5965. Gose, E. E., On the separation of gas mixtures in a jet, *AIChE J.* **6,** 1, 168–170, Mar. 1960.

Becker showed that components of gas mixture could be separated by allowing jet of mixture to expand in low-pressure chamber with heavier molecules concentrating near center of jet. Paper predicts this effect from kinetic theory of gas, including correct magnitude. N. Curle, England

5966. Eichhorn, R., Effect of buoyancy forces on mass transfer cooling, AFOSR TN 60–64 (Univ. Minn., Inst. Technol., Heat Transf. Lab., Mech. Engng. Dept. TR–25), 15 pp., Feb. 1960.

Consideration is given to the constant property laminar boundary-layer equations with free convection and mass transfer. It is shown that similar solutions are possible for blowing rate distributions varying as the distance from the leading edge raised to the power $(n - 1)/4$, where n is the exponent in a power law surface temperature distribution. Solutions to the equations in the form of skin friction and heat-transfer parameters, and velocity and temperature profiles are presented for the constant wall temperature case for a fluid with $Pr = 0.73$. The cases considered range from strong suction to strong blowing.

Mass transfer has a pronounced effect on the heat transfer but only a slight effect on the skin friction. In light of the solutions presented these effects are shown to be physically rational.

From author's summary

5967. Myers, H., Aerodynamically heated surfaces—a chemical analysis, *Aero/Space Engng.* **19,** 2, 34–38, Feb. 1960.

Teflon is used to illustrate method of analysis of ablative missile surfaces, including both decomposition reactions and mass transfer, that is applicable to any surface material for which reaction kinetics of decomposition are known. Teflon and its decomposition are described. Variation of heat of decomposition with heat flux and dependence of rate constant on temperature are given. Method for finding effect of decomposing Teflon on missile skin temperatures is concisely described. Graph of skin temperature against time shows that missile skin of Teflon coated steel reaches a maximum temperature about one fifth of that reached by an uncoated steel skin during a flight of 110 seconds. Mislabeled figure shows effect of mass transfer of decomposing Teflon on heat-transfer coefficient of turbulent boundary layer. Effective heat of ablation is defined and variation of heat of ablation of Teflon with Mach number up to Mach number 35 is shown. At Mach number of 24, effective heat of ablation is three times that at zero.

N. Tetervin, USA

5968. Geller, F. J., The effect of film cooling for highly heated structural components (in German), Jahrbuch Wissenschaft. Gesellsch. Luftfahrt, 1957, 134–138.

This is a preliminary report on cooling of gas turbine blades by locally blowing air through holes or slits arranged in a row parallel to the leading edge and placed some distance downstream of it. The holes and slits were oblique to the surface and air was injected at an angle of 40° against the downstream local flow direction. If the coolant mass flow was 3% of the whole mass flow and the gas temperature 1000°C, the temperature reduction as compared with the uncooled blade was about 600°C near the holes where air was blown out, but decreased to about 200°C near the trailing edge. Experiments are to be continued and final conclusions on the efficiency of this method of cooling are postponed until later. H. Schuh, Sweden

5969. Anderson, G. E., Scott, C. J., and Elgin, D. R., Mass transfer cooling experiments on a hemisphere at M = 5, AFOSR TN 59–1306 (Univ. Minn. Inst. Technol., Rosemount Aero. Lab. Res. Rep. 166), 30 pp., Aug. 1959.

Basic thermal data are presented for helium injection through a porous sintered stainless steel shell. Heat-transfer rate is reduced with increasing injection but is 30% higher than the stagnation point analysis of Hoshizaki and Smith [Lockheed LMSD–48379, Dec. 1958]. The latter corresponds to a temperature ratio (wall to stream) of 0.37 in contrast to test at 0.90. Analytical results by Baron and Scott [MIT NSL TR 419, 1960] for 0.80 lie between. Reviewer believes major finding is presence of recovery temperatures appreciably higher (60° F) than operating stagnation temperatures despite its description in a section entitled "Errors." J. R. Baron, USA

5970. Trapanese, G., On the influence of the mass transport on the convection coefficient: Part I, Experimental research—Consideration of the dynamic boundary layer limit with suction; Part II, On the suction-controlled thermic laminar boundary-layer for Prandtl numbers ≥ 1 (in Italian), *Aerotecnica* **38,** 3, 171–180, June 1958; **38,** 4, 234–240, Aug. 1958.

Paper concerns the influence of the atmospheric vapor condensation on the convection coefficient in the flow along a plate. Problem is dealt with as a heat-transfer problem with boundary-layer suction, using Karman's approximate method.

First two parts describe author's experiments which show that, in case of condensation, the mean convection coefficient is higher than that obtained when condensation does not take place, and that for both cases this coefficient increases with the flow velocity. Assuming an homogeneous incompressible fluid with constant physical properties, author finds the thickness of the dynamic boundary layer δ with or without condensation. For this purpose, it is considered that the condensation effect is to introduce the velocity v_0 normal to the plate which is assumed to be porous. Considering that Prandtl number is $Pr \leqslant 1$, the thickness of the thermic boundary layer is calculated under the same conditions.

N. S. Tipei, Roumania

5971. Trapanese, G., On the influence of the mass transport on the convection coefficient, Part III: Thermic boundary layer with suction in laminar flow for Prandtl numbers $\leqslant 1$ (in Italian), *Aerotecnica* **38,** 5, 285–292, Oct. 1958.

The last part of this paper [see preceding review for Parts I and II] discusses the problem considering that Prandtl number is $Pr \geqslant 1$. Author shows that the value $Pr = 1$ corresponds to the case when the dynamic and thermic boundary layers have the same thickness. The local convection coefficient is deduced and it is shown that the ratio $\rho = (\delta t/\delta)$ increases with v_0 for $Pr \leqslant 1$ and decreases for $Pr \geqslant 1$. The boundary-layer suction corresponds to an increase of the heat-transfer coefficient for $Pr \geqslant 0.4$ and to a de-

crease of this coefficient for $Pr \leqslant 0.2$. A comparison of the theory with experimental data shows generally a fairly good agreement, although the fact that only mean values of the transfer coefficient are experimentally deduced and that ν_0 cannot be accurately deduced raises difficulties from this viewpoint.

Reviewer believes that paper brings new contributions to the problem of heat-transfer flows. Although the use of polynomials for various developments results in lengthy calculations, the final results are generally in a simple form.

N. S. Tipei, Roumania

5972. Steele, L. R., and Geankoplis, C. J., Mass transfer from a solid sphere to water in highly turbulent flow, *AIChE J.* **5,** 2, 178–181, June 1959.

Mass transfer coefficients from ½-in. spheres of benzoic and cinnamic acids and 2-napthol to water were measured in the high Reynolds number region of 600 to 140,000. Previous data for liquids extended only to a Reynolds number of 11,000. Three separate and approximately parallel lines of J_D vs. Reynolds number were found for the different solutes, and the shape of the curves was found to be similar to the total-drag-coefficient correlation for spheres.

Experiments with benzoic acid and 2-napthol showed an effect of driving force and hence flux on the J_D values. Mass transfer did occur in saturated solutions having zero driving force. When one subtracted the amount of mass transfer at zero driving force from the values at other driving forces, the corrected J_D values at different driving forces were the same for a given solute. Possible explanations may be the effect of extreme turbulence on crystallization or physical attrition. From authors' summary

5973. Severson, D. E., Madden, A. J., and Piret, E. L., Evaporation rates of liquids to flowing gas streams, *AIChE J.* **5,** 4, 413–418, Dec. 1959.

Measurements were made of evaporation of various liquids into air and helium for laminar flow in a pipe. Low-velocity gas streams at low pressures were employed to give high concentration gradients and high evaporative velocities. It was found that the results correlated well with two previous formulations for a simplified version of this flow. The fractional saturation of the resultant gas flow was demonstrated to be a single-valued function of the Graetz number, and conventional Sherwood and Schmidt number relation to the Reynolds number was verified.

Reviewer thinks that paper will be of interest only to chemical engineers interested in evaporation in laminar flow at low pressures. W. D. Baines, Canada

5974. Kurihara, H. M., and Myers, J. E., The effects of superheat and surface roughness on boiling coefficients, *AIChE J.* **6,** 1, 83–91, Mar. 1960.

Paper presents the results of an experimental investigation for pool boiling of water, acetate, *n*-hexane, carbon tetrachloride and carbon disulfide on a horizontal surface at atmospheric pressure. The apparatus, the procedure of obtaining a reproducible surface roughness, the roughness measurements are discussed and the experimental errors estimated. The mean boiling heat-transfer coefficient, h_m, was correlated by the dimensionless groups suggested by Rohsenow [*Trans. ASME* **74,** p. 969, 1952; see also AMR **5**(1952), Rev. 1879]. The authors found that h_m was approximately proportional to 1/3 power of the number of active nucleation centers per unit area, n. This exponent is in fair agreement with the value of 0.43 reported by Gaertner and Westwater [ASME-AIChE Third National Heat Transfer Conference, August 1959, AIChE Preprint 103]. The correlation fits the data reasonably well for all liquids for values of n larger than 200 ft^{-2}.

By starting from Frenkel's nucleation theory, authors have derived a semiempirical equation which relates the temperature difference driving force to n. The number of active nuclei thus predicted were compared with the experimental data for various surface finishes and all liquids except water, for which no comparisons were made. The results of further investigations are awaited so that a more general correlation for the entire range of nucleate boiling, in which the surface condition as well as nucleation and bubble dynamics are treated as variables, could be formulated.

R. Viskanta, USA

5975. Charlesworth, D. H., and Marshall, W. R., Jr., Evaporation from drops containing dissolved solids, *AIChE J.* **6,** 1, 9–23, Mar. 1960.

Part I of the paper presents results of an experimental investigation of the evaporation of single drops of water containing dissolved inorganic salts heated in air under atmospheric pressure. The main parameters under investigation were: (1) air temperature; (2) air velocity; (3) droplet diameter; (4) initial solute concentration; and (5) ratio of the initial concentration to the saturation concentration. Experimental apparatus and technique are described in detail, and data for various conditions of operation are reported in 20 separate figures, some containing several parameters. First, a mathematical formulation was obtained by considering a simple physical model which approximates the drying droplet. The nonsteady diffusion equation in spherical coordinates with appropriate boundary conditions was solved, and the approximate solution was used to correlate experimental data. The final correlations give the time of first appearence of crystals and the time of crust formation.

In Part II of the paper practical value of the observations and correlations reported in Part I is illustrated by performing design calculations for a specific spray dryer. In addition, the physical mechanism of the first and second period of drying are thoroughly discussed. The paper is a welcome contribution to a field which has received little attention. R. Viskanta, USA

5976. Kays, W. M., The basic heat transfer and flow friction characteristics of six compact high-performance heat transfer surfaces, *ASME Trans.* **82** A (*J. Engng. Power*), 1, 27–34, Jan. 1960.

Performance is presented for six very compact heat exchanger surfaces which utilize strip fins, perforated fins, or wavy fins. In some cases a multiple sandwich arrangement is used which shows a sensitivity to flow distribution.

Paper is a valuable addition to the previously reported work of author and associates. R. H. Eustis, USA

5977. Mennicke, U., Heat transfer in plate heat exchangers (in German), *Kältetechnik* **11,** 9, 278–284, Sept. 1959.

Paper considers theoretically the calculation of heat transfer in a plate heat exchanger in which the fluids flow either in parallel or counterflow. The author prefers to modify the usual over-all heat-transfer coefficient instead of the log-mean temperature difference and hence defines as a new variable the ratio of the apparent heat-transfer coefficient to the "true" heat-transfer coefficient. This variable is a function of two dimensionless quantities: one the product of the area multiplied by the true H. T. coefficient divided by product of mass flow times specific heat; the other the ratio of the heat capacities of the fluids.

The method of calculation is indicated by examples and results are tabulated in some cases.

Reviewer feels the paper to be useful for those concerned with similar heat-exchangers, but would prefer the mean temperature modified by a factor instead of the heat-transfer coefficient.

W. A. Wolfe, Canada

5978. Pohle, R., Investigations of air duct systems of steam generators for determining mass flow and pressure distribution (in German), *Brennstoff-Wärme-Kraft* **12,** 3, 108–113, Mar. 1960.

The drag coefficients for the built-in components and shapes as they are used with steam generators and the characteristics of

control dampers are measured. It is shown that the problem of air distribution in air duct systems of steam generators can also be solved with an electric analog using a simple method of operation. The limits of application of the method are given.

From author's summary

5979. Kravetz, V. F., and Stepanchuk, V. F., The calculation of regenerative heat exchange apparatus with revolving attachment (in Russian), *Inzhenerno-Fizicheskii Zh.* **3,** 3, 133–137, Mar. 1960.

By applying operational calculus methods the basic regularities of operation of regenerative heat-transfer apparatus on direct current have been discovered.

These relationships permit checking as well as construction calculation of this type of apparatus. From authors' summary

5980. Kunii, D., and Smith, J. M., Heat transfer characteristics of porous rocks, *AIChE J.* **6,** 1, 71–77, Mar. 1960.

Equations are derived for predicting the effective thermal conductivity of beds of both consolidated and unconsolidated particles containing stagnant fluid. The effective thermal conductivity at these conditions, called the stagnant conductivity, is a function of the thermal conductivities of the solid and fluid phases, the void fraction, and, if radiation is important, the emissivity, mean temperature, and diameter of the solid particles. Comparison with the available experimental data indicates that the equations are satisfactory for fluids and solid particles of both high and low thermal conductivities. The equations also correctly predict the effect of void fraction and solid and fluid thermal conductivities on the heat-transfer properties of sandstones and sintered metal systems.

J. A. Clark, USA

5981. Korach, M., Theory of tunnel kilns and the so-called "Sandwich" fast schedule firing, Part 1: Theoretical experiments on kiln-models (in French), *Acts Techn., Acad. Sci. Hungaricae, Budapest* **11,** 1/2, 161–184, 1955.

Aim of the present study is to demonstrate the effect of the dimensions of tunnel kilns on the thermodynamical conditions prevailing with kiln models working under ideal circumstances. Evidence is furnished to the effect that the length of the kiln is, in any case, in direct proportion to the output and is, in the case of full equalization of temperature of the fired articles, independent of any other parameter. Specific loss of heat is, in this case, in direct proportion to the side length of the quadratic cross section of the object to be fired passing through the kiln. Consequently, the loss of heat will be, independent of the output, the lower, the smaller is the cross section of the kiln. It appears, therefore, practical to increase the output by increasing the length rather than the cross section of the kiln, while the cross section should be reduced to a minimum admitted by the dimensions of the article to be fired.

To characterize tunnel kilns, the author proposes the use of a dimensionless criterion called Grum number, which is independent of kiln dimensions. From author's summary

5982. Korach, M., Theory of tunnel kilns and the so-called "Sandwich" fast schedule firing, Part 2: Theoretical models for normal and for "sandwich" type kilns (in French), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **25,** 1/2, 25–62, 1959.

The second part of the paper [see preceding review] deduces the operating cost equation first for the normal tunnel kiln, then deals with the so-called "Sandwich" firing and deduces its operating cost equation, based on specific amortization and on specific heat consumption. Starting from the Fourier equation it is proved that the heating-up time of the treated material is proportionate to the square of the side of its cross section for normal tunnel kilns, and that this time is proportionate to the thickness of the material (height of a horizontal rectangle) with "sandwich" type kilns. The *Grum* number is analyzed for similar and for non-similar tunnel kilns, as well as the relations between this number and the specific heat consumption. Finally, a theoretical and practical comparison is made between the two type of kilns, from an economic point of view. From author's summary

5983. Thomas, P. H., and Smith, P. G., Simple dosage meter for high-intensity thermal radiation, *J. Sci. Instrum.* **37,** 3, 73–76, Mar. 1960.

A simple radiation dosage meter which uses the melting of a temperature-sensitive paint as an indicator is described. Calibration curves are given for two versions, one suitable for 5–18 cal cm^{-2}, the other for 16–60 cal cm^{-2}. An approximate theoretical analysis is also given.

From authors' summary by J. A. Clark, USA

Book—5984. Van Es, J. P., Heat and mass transfer by condensation of a binary vapor mixture [Wärmte-en Stofoverdracht bij Condensatie van een Binair Dampmengsel], 'S-Gravenhage, Uitgeverij Excelsior, Oranjeplein 96, 1957, 105 pp. (Paperbound)

The processes governing heat and mass transfer of a condensing two-phase vapor are too complicated to expect that a simple model of them could be found from which a generally valid theory could be derived. E.g., the vapor may not remain saturated, the condensate may be overheated or undercooled; the vapor temperature varies both in the direction of the vapor stream over the heat-transfer surface and normal to it, and thus the temperature of the interphase vapor-liquid is markedly different from the average vapor temperature.

In an effort to obtain a better understanding for these phenomena, experiments were conducted with a turbulent stream of a benzene-toluene mixture. After conducting tests with the components alone that confirm Nusselt's theory and show the adequacy of the chosen vertical condenser tube test set-up, the two phase tests were conducted in close comparison with results of a comprehensive theoretical study. One main problem in making these comparisons lies in the determination of the temperature of the liquid-vapor interphase which is an important parameter in the theory; therefore, a direct check of theory by experiment failed. However, indirect methods lead to agreements that seem to prove basically the validity of the theoretical approach

The paper is thoroughly written, contains good figures of the test equipment and comprehensive tables of the physical constants used, making it very suitable for use as reference and source for similar studies. Considering the importance of the problem for many engineering applications, a study of the paper by workers in the field is highly recommended. H. J. Ramm, USA

5985. Kaganov, M. A., and Rozenshtok, Y. L., The accuracy of measurement of heat flows with heat flow meters (in Russian), *Inzhenerno-Fizicheskii Zh.* **3,** 3, 138–142, Mar. 1960.

The error in the measurement of heat flow with thermoelectric heat-flow meters is analyzed. This error is casued by two factors: (a) substitution of the temperature gradient by ratio of the temperature overfall on the transducer plate to its thickness (unsteady-state conditions), (b) distortion of the heat-flow pattern when the heat conductivities of the undisturbed media and of the transducer plate are not equal (steady-state conditions).

From authors' summary

Chronicle of heat and energy, *Brennstoff-Wärme-Kraft* **12,** 4, Apr. 1960.

This symposium contains 26 short papers describing recent developments in this field. They were prepared in connection with the German Industrial Fair, Hannover, 1960.

Below are listed titles of some papers of interest to AMR readers. (Revs. 5986–5999). Ed.

5986. Bachmair, A., Steam generators (in German), 144–146.

5987. von Swietochowski, O., Brown coal and furnaces (in German), 147–149.

5988. Rosahl, O., Oil furnaces (in German), 149–151.

5989. Nagel, R., Flue dust removal (in German), 153–154.

5990. Honold, E., Boiler feed pumps (in German), 156–158.

5991. Rosenlocher, O., Steam turbines (in German), 159–162.

5992. Raabe, J., Hydraulic prime movers (in German), 162–165.

5993. Thomann, E., Heilig, J., and Kluge, L., Compressors (in German), 165–167.

5994. Schwiedessen, H., Industrial furnaces (in German), 167–168.

5995. Kneule, F., Drying technics (in German), 168–169.

5996. Kollmar, A., Heating, ventilating and air conditioning (in German), 170–171.

5997. Luck, G., Heat exchangers (in German), 171–172.

5998. Seiffert, K., Heat and cold insulation (in German), 172–174.

5999. Pressler, G., and Schneider, K., Measuring and automatic control (in German), 174–177.

End of Symposium

Combustion

6000. Hirschfelder, J. O., and Van Domelen, Sarah S., Propagation of flames by a zeroeth-order chemical reaction, *Physics of Fluids* **3,** 2, 210–216, Mar./Apr. 1960.

Numerical solutions are presented for burning velocity and structure of a one-dimensional adiabatic steady-state model of a gaseous flame for which the reaction rate is independent of species concentration, depending only on an Arrhenius temperature law and terminating sharply when a given enthalpy has been released. Authors suggest that these results may provide a starting point for theoretical study of multidimensional or unsteady-state flames.

R. Friedman, USA

6001. Rosen, G., An action principle for the laminar flame, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28–Sept. 3, 1958; New York, Academic Press, 1959, 339–341.

Primarily a mathematical article which develops an equation for the burning velocity eigenvalue in terms of the "centroid temperature," τ_c. Spalding's centroid rule is deduced theoretically.

J. H. Davidson, India

6002. Bacigalupi, R. J., and Lezberg, E. A., Blowoff of propane and hydrogen diffusion flames at high Mach number, ramjet conditions, NASA TN D-67, 24 pp., Dec. 1959.

Flames were stabilized in the wake of cylindrical fuel injectors at ramjet burner inlet conditions. The effect of varying pressure, temperature and air and fuel flows was determined for several fuel orifice tube sizes.

Using exponents instead of linear weights, propane and hydrogen blowoff data were correlated to air flow velocity for 0.188 and 0.20-inch diameter tubes. These correlations were derived from a thermal ignition model for flame stabilization. The treatment of the data is illustrated fully by graphs. The effect of increasing fuel flow was found to be destabilizing except for hydrogen at low pressure. At equal fuel mass velocities the orifice size was optimum at 0.04 to 0.05 in. The ratio of the stabilities of the two fuels was roughly equal to the ratio of their flame speeds at high inlet temperatures.

J. H. Davidson, India

6003. Fraser, R. P., Detonation velocities in liquid fuel vapors with air or oxygen at 100°C and atmospheric pressure, Seventh Symposium (International) on Combustion, London and Oxford, Aug. 28–Sept. 3, 1958; New York, Academic Press, 1959, 783–788.

Velocities were measured in a glass tube, 13-mm bore, 1.5 m long surrounded by a steam jacket at 100°C. With oxygen-octane mixtures, limit speed of 1,660 m/sec occurs at 1.55% and maximum of 2,540 m/sec at 17.5% (saturation limit). Oxygen-benzene gives lower limit of 1,570 m/sec at 2%, maximum of 2,510 m/sec at 21.3%, decreasing rapidly to 1,800 m/sec at 37.5%, upper limit of detonation.

With air, velocities are lower—1,540 to 1,760 m/sec. Ethyl alcohol and petrol were also tested with air. Observed failure to detonate mixture of benzene-air in range 4.1% to 5.0% benzene, but no explanation is offered. In all cases, detonation was initiated by a detonation wave of mixture of butane and oxygen, having similar speed to mixture being tested.

Carbon formation on walls of tube increased with fuel concentration. Tentative explanations are offered as to mechanism of breakdown. At high fuel concentration it is suggested that benzene molecule breaks down prior to combustion.

D. Aronson, USA

6004. Rosen, G., Nonlinear pressure oscillations in a combustion field, *ARS J.* **30,** 4, 422–423 (Tech. Notes), Apr. 1960.

Unsteady-state equations are derived to describe combustion of liquid droplets in a one-dimensional flowing gas, a differential equation for nonlinear pressure oscillations being obtained. The significance of terms in this equation is discussed and criteria for instability are proposed.

R. Friedman, USA

6005. Kvashnina, S. S., and Chernyi, G. G., Steady-state flow of detonating gas around a cone, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23,** 1, 252–259, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The steady flow of a gas, capable of detonation, past a cone is discussed in an analogous fashion to the corresponding wedge problem studied by J. Rutkowski and J. A. Nicholls [Proc. Gas Dynamics Symp. on Aerothermochemistry, Evanston, Ill., 1956].

The first disturbance to the uniform flow ahead of the cone is through a detonation wave. Conditions are found for the occurrence, between this detonation wave and the cone, of compression zones, rarefaction zones, shock waves either alone or in combination.

K. Stewartson, England

6006. Grosse, A. V., and Stokes, C. S., Study of ultra high temperatures, AFOSR TR 59-168 (Research Inst. of Temple University, Philadelphia), 26 pp., Apr. 1959.

This report is mainly a recapitulation of work previously published by the authors or other investigators working at the Research Institute of Temple University. The new (unpublished) sections deal with high-temperature flame calorimetry, metal-metal oxide (Be, $Zr + Al_2O_3$) condensed phase reactions, metal-oxygen (Be, $Zr + O_2$) flames, and unsuccessful attempts to prepare compounds of the carbon-phosphorous type.

In the reviewer's opinion this report has little general utility because it is poorly written and extremely cursory in nature. It overemphasizes what was studied and underemphasizes what was

found. It is disjointed to the point of being difficult to understand and, as written, it has little research value. It does, however, contain references to all work published under this contract in the open literature as well as the Air Force technical notes published.

R. A. Strehlow, USA

6007. Thomas, P. H., Studies of fires in buildings, using models, Part 1, Experiments in ignition and fires in rooms; Part 2, Some theoretical and practical considerations, *Res. Appl. Indust.* **13,** 2, 69–77, Feb. 1960; **13,** 3, 87–93, Mar. 1960.

In the last few years, there has been a growing interest in the basic theory of fires, a problem of obvious practical importance. The present work describes studies motivated by the need to establish regulations for the many new construction materials coming into use. The economy of small-scale experiments in this field is obvious.

In the first part, results on ignition and fires in single compartments are given. It is shown that there are two distinct burning regimes: poorly ventilated fires where the burning rate is proportional to the air supply and well ventilated fires where the rate is proportional to fuel area.

In the second part, model tests of the induced air flow are described and the problem of computing the burning rate considered. It is concluded that present knowledge is insufficient. Finally the size of the flame and the radiation are considered, as these factors are important in evaluating the risk to nearby buildings.

While the treatment of the individual topics is brief, there is an extensive bibliography. Reviewer believes this is an interesting survey of a field which deserves considerable attention.

W. Squire, USA

Prime Movers and Propulsion Devices

(See Revs. 5882, 5902, 5928, 5956, 5968, 5976, 5991, 5992, 6070, 6074)

Magneto-fluid-dynamics

(See also Rev. 6072)

6008. Cowley, M. D., A magnetogasdynamic analogy, *ARS J.* **30,** 3, 271–273 (Tech. Notes), Mar. 1960.

This note presents an analysis that describes the transformation of an axially symmetric magnetogasdynamic flow into an ordinary axially symmetric gasdynamic flow. The transformation requires the following conditions: (a) the fluid has an infinite conductivity, (b) the electric field is zero throughout the flow, and (c) the magnetic field is proportional to the mass flux. It is also required that there is no magnetic field inside the body. It is shown that the transformed flow is hyperbolic for both fast and slow magnetogasdynamic waves and is elliptic when the fluid velocity either is larger than the speed of sound or the Alfven speed and is smaller than either the Alfven speed or the speed of sound, respectively. Finally there is an elliptic region corresponding to a negative transformed Mach number. This flow has no analogous gasdynamic flow.

The principal contribution in this note is the extension of the potential flow analogy to axially symmetric flows. The application of this type of transformation can lead to a better understanding of certain processes.

E. E. Covert, USA

6009. Riazanov, E. V., The solution of the equation of magnetohydrodynamics describing the one-dimensional axisymmetrical motion of a gas in a gravitational field, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23,** 1, 260–265, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The gas is assumed to be moving unsteadily in a direction perpendicular to the axis of symmetry and to be inviscid, to be electrically a perfect conductor, and to have a negligible thermal conductivity. The magnetic lines of force are helical. It is shown that an exact solution of the governing equations can be found in which the fluid velocity is proportional to distance from the axis. The properties of this solution are discussed in some detail and conditions found for stable equilibrium and for the complete dispersion of the gas.

K. Stewartson, England

6010. Tkalich, V. S., Transformation of the system of equations of the hydrodynamic approximation of a plasma, *Izv. Akad. Nauk USSR, Otd. Tekh. Nauk, Ser. Mekh. i Mash.* no. 5, 122–123, 1959. (Translation by Morris D. Friedman, Inc., P. O. Box 35, W. Newton, Mass., T-138, 3 pp.)

The system of equations comprising the hydrodynamic approximation for the motion of N kinds of ions in a plasma, which is assumed to be a uniformly charged, incompressible, ideal fluid, is transformed into a vector equation and then formally solved. No applications of the formal solution are made and the paper has no engineering significance.

L. C. Woods, England

6011. Zeuli, T., On magneto-fluid-dynamical circular cylindrical vortex (in Italian), *Atti Accad. Sci. Torino* **92,** 1, 105–114, 1957/58.

An incompressible inviscid homogeneous conducting infinite fluid is considered. For the corresponding equations of magnetodynamics particular solutions are studied, with a magnetic field $\overline{H} = \Phi(x, y, t)\,\overline{k}$ and a velocity $\overline{v} = \text{grad}\,\Psi(x, y, t) \times k$ (Φ and Ψ are functions which one must calculate, $\overline{k}$ is the unity vector of the axis z). Using a particular Φ and Ψ, an infinite circular cylindrical vortex, with axis z and with stationary velocity, is obtained. Into the interior and exterior of the vortex, velocity (which is only transverse), magnetic field and pressure are calculated; there is no discontinuity through the boundary of the vortex. The cylindrical homogeneous vortex is also studied, with a Φ dependent on the azimuthal angle.

R. Nardini, Italy

6012. Tao, L. N., Magnetohydrodynamic effects on the formation of couette flow, *J. Aero/Space Sci.* **27,** 5, 334–338, May 1960.

Author studies the problem of how the velocity profile of an electrically conducting viscous fluid between two parallel nonconducting plates, one of which is moving with constant speed, varies with time tending asymptotically to that of the steady flow in the presence of a magnetic field. The problem is formulated mathematically and solved by means of Duhamel's theorem for the cases of both vanishing and nonvanishing mean induced electric field strengths. The result is rather lengthy and so is discussed numerically for the first case only. It shows that the flow rate of the steady flow is reduced and that the steady flow is reached earlier when the magnetic field increases.

F. Engelmann, France

6013. Demetriades, A., A possible "fully developed" hydromagnetic pipe flow, *J. Aero/Space Sci.* **27,** 5, 388–389 (Readers' Forum), May 1960.

6014. Yasuhara, M., Flow of a viscous, electrically conducting fluid along a circular cylinder or a flat plate with uniform suction, *J. Phys. Soc. Japan* **15,** 2, 321–325, Feb. 1960.

Author extends the known boundary-layer flow over a circular cylinder or a flat plate with uniform suction to the case where the fluid is electrically conducting and an externally magnetic field is imposed normal to the wall. He derives an exact analytical solution for this problem for incompressible flow which shows that

the applied magnetic field acts on the flow to decelerate it and reduces the skin friction. Velocity profiles are given for several values of the magnetic field and two pairs of the hydrodynamic and magnetic Reynolds numbers. K. Pohlhausen, USA

6015. Kerrebrock, J. L., Similar solutions for boundary layers in constant-temperature magneto-gasdynamic channel flow, *J. Aero/Space Sci.* **27,** 2, 156–157 (Readers' Forum), Feb. 1960.

Existence of similar boundary-layer solutions is demonstrated for one class of flows through an accelerator with crossed electric and magnetic fields. Solutions are analogous to those of Falkner and Skan since core velocity varies as a power of the longitudinal coordinate. Temperature, electric field and electrical conductivity are assumed constant, and magnetic Reynolds number and boundary-layer thickness are taken to be small. Closed-form solutions for the inviscid core flow had been developed in a previous paper [*J. Aero/Space Sci.* **27,** 1, p. 78, Jan. 1960] and the resulting electric current and pressure distributions were employed in this paper. The similar solutions are valid for only a portion of the subsonic part of the accelerator, since it was necessary to assume the core Mach number small. Apparently no actual numerical results have yet been obtained.

A. L. Loeffler, Jr., USA

6016. Long, R. R., Steady finite motions of a conducting liquid, *J. Fluid Mech.* **7,** 1, 108–114, Jan. 1960.

It is shown that the equations for the steady axisymmetric flow of a frictionless incompressible and infinitely conductive fluid in a magnetic field can be reduced to a single nonlinear second-order equation in the stream function. Some soluble cases are indicated. A short discussion on the question whether to apply upstream or downstream boundary conditions is given.

L. J. F. Broer, Holland

6017. Cole, J. D., and Huth, J. H., Some interior problems of hydromagnetics, *Physics of Fluids* **2,** 6, 624–626, Nov./Dec. 1959.

Authors compute, in two dimensions for the case of infinite electric conductivity, (1) the shape of the cavity formed by a magnetic dipole in a liquid under initial hydrostatic pressure, and (2) the shape of the cavity formed by an isolated line current submerged in a uniform, inviscid incompressible flow. The dipole cavity has a shape resembling a figure-of-eight, whereas the line-current cavity is elliptical, with major axis perpendicular to the free stream.

Authors suggest that these shapes should be stable with respect to small disturbances, although no stability analysis is presented. They also state that their solutions may be useful as a starting point for examining interactions between moving streams and magnetic fields in more complicated cases.

H. A. Stine, USA

6018. Ramamoorthy, P., Superposability of two axisymmetric flows under axisymmetric magnetic fields, *Appl. Scient. Res. (A)* **9,** 2/3, 153–156, 1960.

In this note the two following theorems are established. An axisymmetric flow of an infinitely conducting fluid under axisymmetric magnetic field is always self-additive. Two axisymmetric flows of an infinitely conducting fluid are superposable if the fluid velocity is parallel to the magnetic field in each of the two flows.

From author's summary

6019. Rand, S., Wake of a satellite traversing the ionosphere, *Physics of Fluids* **3,** 2, 265–273, Mar./Apr. 1960.

Particle treatment is applied to a study of the wake structure behind a charged body moving supersonically through a low-density plasma. For the case of a body whose dimensions are considerably smaller than a Debye length, a solution is obtained which is very similar in structure to the solution obtained by using the linearized fluid dynamics equation. For the case of a disk whose radial dimensions are much larger than a Debye length, two conical regions are found in the wake.... Formulas for the electrohydrodynamic drag on a wire and on a large disk are obtained.

From author's summary by W. Fiszdon, Poland

6020. Bleviss, Z. O., A study of the structure of the magneto-hydrodynamic switch-on shock in steady plane motion, Douglas Aircr. Co. Rep. SM-23720, 33 pp., Oct. 1959.

"The structure of the steady magnetohydrodynamic switch-on shock wave is investigated for several order-of-magnitude orderings of the four diffusivities involved in the problem. The various orderings are approximated by allowing one or more of the appropriate diffusivities to approach zero, and approximate solutions that are uniformly valid to order unity are sought. In general, singular perturbation problems are encountered, the number of them (from zero to a maximum of three) depending upon the ordering of the diffusivities and the magnitude of the downstream velocity normal to the shock relative to certain critical velocities downstream of the shock. Where necessary, the approximate solutions are rendered uniformly valid to first order by the insertion of boundary layers, for which the approximate equations are determined to first order. For most of the cases considered, the limiting forms of the integral curves are determined and they are sketched in appropriate three-dimensional phase spaces." (From the author's summary.)

Report is clearly written and well worth careful study. It is not self-contained but depends rather heavily on two preceding works by the same author. One of these, Douglas Report SM-23608, discusses in detail the case where magnetic diffusivity is large compared with viscous and thermal diffusivities. This case serves as a prototype for all others treated. As a minor criticism reviewer had to go to the earlier report for definition of "longitudinal coefficient of viscosity." More importantly, the fundamental conservation equations in the general form used by the author are not given in either report but may be found, stated practically without comment, in an earlier published paper of the author. Considering the difficulty which may attend obtaining a correct form of the mhd energy equation in a moving medium (for which see B. T. Chu, *Physics of Fluids* **2,** p. 473, 1959; AMR **13**(1960), Rev. 3108], reviewer examined author's formulation in considerable detail and ultimately found it to agree with that of Chu.

F. D. Bennett, USA

6021. Patrick, R. M., Experimental dependence of the collision-free shock thickness upon Alfvén Mach number, *Physics of Fluids* **3,** 2, 321–323 (Letters to the Editor), Mar./Apr. 1960.

6022. Bazer, J., and Fleischman, O., Propagation of weak hydromagnetic discontinuities, *Physics of Fluids* **2,** 4, 366–378, July/Aug. 1959.

By means of J. B. Keller's "geometrical acoustics" approach [AMR **9**(1956), Rev. 321], authors examine the development of a given weak hydromagnetic disturbance in an infinitely conducting, perfect, compressible fluid. In general, there are six different wave fronts and rays, as well as the exceptional "conical" mode of propagation. A geometrical construction of wave fronts is given and two special cases, namely that of a given initial spherical disturbance and a moving infinitely conducting magnet, are examined in detail. Formulas describing the variation of shock strength along rays of a given propagating mode are derived. This elegant paper is somewhat terse; readers should consult authors' original report [Inst. Math. Sci., N. Y. Univ. (1959), Rep. no. MH. 10] for greater detail. P. Savic, Canada

6023. Iordanskii, S. V., On compression waves in magnetohydrodynamics, *Soviet Phys.-Doklady* **3,** 4, 736–738, Apr. 1959. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **121,** 4, 610–612, July–Aug. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.)

Relations across a shock wave are examined for the flow of an infinitely conducting gas in the presence of a magnetic field. Equations are given for the Hugoniot curves which define the possible relations between pressure and volume on either side of the shock. It is shown that in the presence of a magnetic field, three Hugoniot curves exist through a point. Since two solutions for the magnetic field in terms of pressure and volume become imaginary at large downstream pressure, two of the Hugoniot curves end at some pressure. The third curve, however, is shown to persist to an indefinitely high pressure.

L. H. Schindel, USA

6024. Stepanov, K. N., Kinetic theory of magnetohydrodynamic waves, *Soviet Phys.-JETP* **7,** 5, 892–897, Nov. 1958. [Translation of *Zh. Eksp. Teor. Fiz.* **34,** 5, 1292–1301, May 1958 by Amer. Inst. Phys., Inc., New York, N. Y.).

Propagation of magnetohydrodynamic and cold plasma waves at arbitrary inclinations to a constant magnetic field has been studied by Astrom [*Ark. Fysik* **2,** 443–457, 1950] and Ginzburg [*Zh. Eksp. Teor. Fiz.* **21,** 788–794, 1951]. Present author, using methods of Vlasov and Landau based on the collisionless Boltzmann equation, develops a more exact treatment including effects of finite temperature. Ion and electron gases constituting the plasma may have different equilibrium temperatures. Various expressions for the dielectric tensor components are obtained, as is a dispersion relation precise enough to exhibit Landau damping.

J. W. Butler, USA

6025. Gershman, B. N., On normal waves in a homogeneous plasma in a magnetic field, Akad. Nauk Press, Memorial Vol. to A. A. Andronov, 1955, 599–605. (Translation by Morris D. Friedman, Inc., P. O. Box 35, W. Newton, Mass., Pap. G-175, 7 pp.)

Longitudinal waves in a homogeneous, isotropic plasma under an external uniform magnetic field have been studied from Boltzmann equation by neglecting the ion motion and the collisions between particles.

S. I. Pai, USA

6026. Koga, T., Transport phenomena of a rarefied and fully ionized gas in the presence of a strong magnetic field, AFOSR TN 60-103 (Univ. So. Calif. Engng. Center Rep. 56-210), 18 pp., Feb. 1960.

This is a generalization of the theory in a previous report by the author by defining moments in general (University of Southern California Engineering Center report 56-209, "Diffusion of a fully ionized gas confined in a strong magnetic field").

S. I. Pai, USA

6027. Zhigulev, V. N., On the phenomenon of magnetic "detachment" of the flow of a conducting medium, *Soviet Phys.-Doklady* **4,** 3, 514–516, Dec. 1959. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **126,** 3, 521–524, May/June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Paper considers flow of a conducting gas around bodies with their own magnetic field. Hypersonic flow of a gas around a current filament is discussed as an example. It is shown that under certain conditions detachment will occur, thus indicating the possibility of a complete isolation of a body from a plasma flowing around it.

D. Ter Haar, England

6028. Lewellen, W. S., An inviscid boundary layer of magnetohydrodynamics, AFOSR TN 59-927 (Cornell Univ., Graduate School Aero. Engng.), 46 pp., Sept. 1959.

The fundamental system of equations consists of two parts: hydrodynamics of an incompressible fluid (continuity and momentum) and magneto-electrodynamics (Ohm's law, Maxwell equations). Two approaches to the solution of the system are proposed: integral method applied to the original partial differential system and a transformation into an ordinary equation system. Prandtl's generalized dimensional analysis is applied to the original partial differential system resulting in simplifications analogous to those in the classical system of the boundary-layer equations. After discussing the boundary conditions, the author applies the Kármán-Pohlhausen integral method to the resulting partial differential system. For the horizontal velocity component and the horizontal magnetic field vector component there are chosen Pohlhausen profiles of quartic polynomials. The solutions of the final equations in integrated forms are a little complicated and the interpretation of how the various parameters affect the boundary layer presents some difficulty.

The second method is that of transforming the partial differential equations into ordinary, using the transformation functions analogous to those of Prandtl-Blasius in the classical theory. The final solutions are assumed in form of series in α, the ratio of Alfven speed to the fluid velocity with the coefficient functions which are found in the usual manner, i.e., by comparing the terms with coefficients of the equal powers of α. The first three functions are calculated. The validity of the solution is assumed with some discussion of its behavior near and at zero and infinity. According to the numerical example, worked out in a tabular form, it seems that convergence is fairly rapid for small values of α.

In the last chapter the author compares the exact and the approximate methods numerically for some particular values of the parameters. The numerical results refer to flow over a wedge, the stagnation flow and the flat plate. In the conclusions the author considers the question of separation and the growing-forward boundary layer around a finite body.

M. Z. Krzywoblocki, USA

6029. Stuetzer, O. M., Instability of certain electrohydrodynamic systems, *Physics of Fluids* **2,** 6, 642–648, Nov./Dec. 1959.

The stability of pressure in a one-dimensional flow between ion emitter and collector was investigated. The flow is assumed to be slowly varying in the analysis. Instability for the case of constant applied voltage was predicted and demonstrated by experiments.

W.-H. Chu, USA

6030. Smirnov, A. G., The theory of certain magnetohydrodynamic phenomena occurring in the free laminar thermal convection of the electrically conducting fluid in a round vertical pipe located in a weak magnetic field, *Soviet Phys.-Tech. Phys.* **4,** 10, 1141–1147, Apr. 1960. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **29,** 10, 1245–1251, Oct. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

An analysis is made which is limited to magnetic fields sufficiently weak so that the velocity distribution remains practically unchanged. The magnetic fields are oriented perpendicular to the axial flow direction. The induced electric currents produce a magnetic viscosity which is proportional to the square of the imposed magnetic field. The vertical temperature gradient which causes the free convective motion must then be increased to compensate for this additional retarding force. The results are in good agreement with experimental data for mercury obtained previously by the author.

R. Siegel, USA

6031. Koga, T., Diffusion of a fully ionized gas confined in a strong magnetic field, AFOSR TN 59-1162 (Univ. So. Calif. Engng. Center Rep. 56-209), 33 pp., Dec. 1959.

Author treats the transport phenomena of a fully ionized gas in the presence of a strong magnetic field. It is shown that there is a certain domain in the density-temperature space where the Boltzmann equation is valid. The mean free path is assumed to be

longer than the mean Larmor radius. An average is taken of the Boltzmann equation along a circular trajectory of gyrating particles. By this method of coarse-graining, the Boltzmann equation is reduced to the equation of diffusion. It is not assumed that the distribution function is close to the Maxwell function. A special case of constant energy per particle is treated in detail. The results are similar to those published by other authors, in spite of author's making no specific assumption of the distribution function: The effect of the collisions between similar particles is negligible, and the ions and electrons diffuse almost at the same velocity. It is easily possible to apply the method to more general cases.

From the author's summary by Mary F. Romig, USA

6032. Josephson, J., On the structure of turbulent electroconvective flow (in French), *C. R. Acad. Sci., Paris* **249,** 8, 876–877, Aug. 1959.

6033. Neuringer, J. L., Optimum power generation from a moving plasma, *J. Fluid Mech.* **7,** 2, 287–301, Feb. 1960.

The possibility exists of directly using the plasma resulting from a controlled fusion reaction to generate electricity by electromagnetic induction. Two special cases of a more general problem are considered here: (1) the extraction of optimum power from the steady one-dimensional flow of an incompressible inviscid plasma across a uniform transverse magnetic field in an externally loaded channel of arbitrarily varying cross section, and (2) the extraction of optimum power from the steady one-dimensional flow of a compressible inviscid plasma across a uniform transverse magnetic field in a channel of uniform cross section. In each case, the magntidue of the required external loading at optimum power operation is determined as a function of the parameters which characterize the hydromagnetic interaction. Also determined are the magnitudes of the terminal voltage, power, fluid mechanical to electrical conversion efficiency, and the variation of the fluid dynamical variables along the channel at optimum power.

From author's summary by C. T. Chang, Sweden

6034. Dickerman, P. J., and Price, C. F., Flow of a partially ionized gas in an axial magnetic field, *Physics of Fluids* **3,** 1, 137–138 (Letters to the Editor), Jan./Feb. 1960.

The research was undertaken to investigate the influence of an axial field on the flow properties and heat-transfer characteristics of an ionized gas in a cylindrical flow channel. The equipment used in the study consists of a plasma generator, mixing chamber, and the test channel surrounded by an air-core solenoid magnet.

From authors' summary

6035. Marshall, J., Performance of a hydromagnetic plasma gun, *Physics of Fluids* **3,** 1, 134–135 (Letters to the Editor), Jan./Feb. 1960.

6036. Sharikadze, D. V., Shape-preserving flows and a point explosion in the magnetic gas dynamics of a gas of infinite conductivity, *Soviet Phys.–Doklady* **4,** 4, 789–793, Feb. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **127,** 6, 1183–1187, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Equations of motion and Ampere's law are given for unsteady flow of gas with infinite conductivity in a magnetic field when there is a center of symmetry. First integral of continuity equation and Ampere's law yield the magnetic field in terms of a function of entropy, gas density and radial distance. Assuming that pressure is equal to the product of another function of entropy and density to c_p/c_v power permits reduction of equations to two ordinary differential equations of the first order and a single quadrature. Conditions on either side of a shock wave which propagates from a point explosion are examined. Results are restricted to a specific current distribution.

Following equation 5 it should read "where for a one-dimensional flow $N = 0$, $m = 0$; when $H = H_z(r, t)$, $j = j_\varphi$ for a cylindrically symmetric flow and $N = 1$, $m = 0$; when $N = 1$, $m = 1$, then $H = H_\varphi$ and $j = j_z$."

A. Fuhs, USA

6037. Shpigel', I. S., Plasma acceleration, *Soviet Phys.–JETP* **9,** 2, 285–289, Aug. 1959. (Translation from *Zh. Eksp. Teor. Fiz., Akad. Nauk SSSR* **36,** 411–415, Feb. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Purely experimental report of "acceleration of plasma in vacuum in an axially symmetric, inhomogeneous, pulsed magnetic field." Pulses of gas are admitted to a 15-cm diameter glass cylinder, pre-ionized by RF, and accelerated by a single-turn, 11.5-cm diameter coil mounted in the tube end plate. The electromagnetic pulse gas valve is not described. Accelerating power is by discharge of a 2.7 μf condenser at voltages from 10 to 24 kv, giving a damped oscillation of about 120 kc.

Optical observations show five to ten luminous bursts at twice the driving frequency. Intensity peaks at the third or fourth burst, as ionization improves. The plasma strikes the wall about 5 cm down the tube and is markedly decelerated. Sample streak pictures of axial and radial motion are presented. Observed energies are stated to be: 0 and N(air), 80–190 ev; H, 40–120 ev, and He, 120–280 ev.

Velocity and pulse shape measurements are made with rf probes. This method gives air plasma velocity of about 3×10^6 cm/sec; discrepancy is attributed to velocity dispersion. Density modulation at discharge frequency is not observed; attributed to velocity spread of ions inside the bunches. Radiating waveguide measurements give densities of 10^{12} electrons/cm^3. Duration of ionization as function of distance from accelerating coil is also observed: maximum 150 μs at 35 cm; 125 μs values at 15 and 65 cm.

Reviewer feels this work rather elementary for its time. Contemporary work has exploited this principle in various ways with refinements. Two examples: plasma injector for Ixion, with addition of axial magnetic field to prevent collision with the tube wall; pre-ionizer for magnetic piston plasma accelerator (reported in Proc., Second Geneva Conf. **31,** p-319 ff, p-341 ff).

A. R. Gruber, USA

6038. Wei, C.-C., Relativistic hydrodynamics for a charged nonviscous fluid, *Physics of Fluids* **3,** 2, p. 323(Letters to the Editor), Mar./Apr. 1960.

6039. Beard, D. B., Relativistic calculation for cyclotron radiation from hot plasmas, *Physics of Fluids* **3,** 2, p. 324 (Letters to the Editor), Mar./Apr. 1960.

Aeroelasticity

(See also Revs. 5559, 5606, 5885)

6040. Milne, R. D., On the estimation of structural damping from aircraft resonance tests, *J. Aero/Space Sci.* **27,** 5, 339–342, May 1960.

It is demonstrated that the cross-damping coefficients in a set of second-order differential equations, representing an elastic system under multipoint sinusoidal excitation, can be determined from knowledge of the normal modes and their required forces. A uniform pinned beam, having sinusoidal uncoupled bending and torsion modes with selected frequencies and damping coefficients, is used in a theoretical example to show how the measured damping coefficients are affected by the number of coupled modes used in the analysis. The number of modes appears to have little influence on the damping coefficients. Reviewer suspects that the

accuracy of the measured modes and a relatively large damping in the supports may have more influence and could prevent the method from being practicable. M. Botman, USA

6041. Clarkson, B. L., Correlation of noise pressures and of the induced strains in an aircraft structure, Univ. Southamption, Dept. Aeronautics and Astronautics Rep. 108, 10 pp., Dec. 1959.

6042. Houbolt, J. C., A study of several aerothermoelastic problems of aircraft structures in high-speed flight (in English), ETH Mitt. Inst. Flugzeugstatik und Leichtbau no. 5, 108 pp., 1958.

This thesis presents a summary treatment of structural problems which are unique for high-speed flights. Application of classical solutions based on mathematical theories of elasticity to practical engineering problems forms a major portion of the paper. A new "summation-equation" method, much akin to the well-known Stodola numerical integration method for vibration modes, is introduced. (This may more properly be considered as an extension of the Marcus method originally devised for solving problems in theory of plates.)

Topics covered in this paper include analysis of temperature within a structural system, stiffness analysis of structures with temperature gradients, flutter analysis, and panel flutter.

C. C. Wan, USA

6043. Vlasov, B. F., Bending of a rectangular plate, moving in a gas with a supersonic velocity (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 12, 124–127, Dec. 1958.

Plate of constant thickness is hinged at opposite sides. Leading and trailing edges are free. It is inclined with respect to direction of motion. Approximate formulas of piston theory as given by A. A. Illyushin are used to determine gas pressure. Stability conditions as given by A. A. Movchan are considered. Formulas for stationary problem are found by author to be useful for estimation of strength and aerodynamic characteristics of plate. Cartesian coordinates are in plane of plate. One axis concides with hinged edge, another one at mid-section. Free ends can be satisfied by any boundary condition within Kirchhoff's theory. At any point of plate small deflections are considered as functions of aerostatic loading which in turn depend on gas pressure at infinity, its polytropic exponent, gas, speed of sound at infinity, plate thickness, Poisson's ratio and Young's modulus. Author employs dimensionless coordinates and linear partial derivative operators, and obtains two real and two complex roots. Real roots appear to be always positive. Sum of roots is equal to zero, product of roots is equal to unity. These conditions provide formulas which appear to be quite useful for finding these roots by nomogram. Author uses general formulas for fourth-power algebraic equations for analysis of roots. Maclaurin series are used to obtain asymptotic formulas. Nondivergent state requires determinant of four algebraic equations is not zero, which indicates existence of unique solution. Problem becomes unidimensional for plate elongated between hinges. For such a case the divergent state does not exist. Stability is insured when reduced Mach number does not exceed reduced flutter velocity. Solution of equations satisfying boundary conditions and its analysis are presented. V. A. Valey, USA

6044. Abramson, H. N., and Chu, W.-H., A discussion of the flutter of submerged hydrofoils, Southwest Research Institute, Dept. Engng. Mech. TR1, Aug. 1958, 33 pp.

Available data relating to flutter in high density fluid media are analyzed. It is stated on the basis of this meager material that rather serious discrepancies exist between theory and experiment. Several possible reasons for this disagreement are examined in some detail, e.g. influence of hydrodynamic load on vibration modes, influence of viscous effects by modifying the Kutta condition, tunnel-wall interference, etc., but none of them alone gives a sufficiently good improvement. It is concluded that until additional experimental data are available, the prediction of flutter in high density fluid media should be approached with care.

H. Bergh, Holland

6045. Dugundji, J., and Crisp, J. D. C., On the aeroelastic characteristics of low aspect ratio wings with chordwise deformations, AFOSR TN 59-787 (Mass. Inst. Technol., Aeroelastic and Structures Research Lab. TN 74-3), 188 pp., July 1959.

Paper consists mainly of aeroelastic analyses on two low-aspect-ratio example wings using piston theory and allowing chordwise flexibility. Results appear in form of several curve sheets and include some effects of aerodynamic heating. Most interesting is an introductory presentation of the flutter matrix and a discussion on its properties for various combinations of chordwise and spanwise modes. It is shown that symmetric and antisymmetric modes can couple to produce flutter provided that aerodynamic damping is not zero. Examples show curves of structural damping versus speed doubling back on themselves–i.e. they indicate that added structural damping can make flutter worse.

C. D. Pengelley, USA

6046. Singh, B. R., and Pearce, C. E., On the aerodynamic excitation of vibration: Part 1, Fluid induced vibration of structures, *J. Sci. Engng. Res., India* **3,** 2, 305–318, July 1959.

The types of problems presented in this paper include such instability phenomena as: the vibration of tall smoke-stacks; submarine periscopes, towing cables and other submerged naval equipment; buffeting of airplane control surfaces; and the wind-induced oscillations of flexible bridge spans. All of these phenomena are related in that they represent vibrations initiated or amplified by energy drawn from the relative flow of the surrounding fluid medium. This paper presents a review of the principles involved and also considers some methods adopted for the solution of these problems. From authors' summary

6047. Murthy, S. N. B., On the aerodynamic excitation of vibration: Part 2, Aerodynamic excitation of compressor blade vibration, *J. Sci. Engng. Res., India* **3,** 2, 319–328, July 1959.

6048. Singh, B. R., On the aerodynamic excitation of vibration: Part 3, Some aspects of stall-flutter of compressor blades, *J. Sci. Engng. Res., India* **3,** 2, 329–350, July 1959.

The fatigue and eventual failure of the aerodynamic blading in axial-flow compressor is often attributed to stall-flutter vibration. Such flutter is encountered at large mean angles of attack and is associated with flow separation during the whole, or at least a part, of the cycle of oscillation. Considerable efforts have been made during the past decade which now lead to a better understanding of this complex phenomenon of aerodynamic excitation. This paper reviews some of the developments with regard to aerodynamic hysteresis, critical velocity of flutter, limit cycles and the related stress problem of the vibrating blades. It is pointed out that further extensive experimental data of the aerodynamic co-efficients, under dynamic conditions of stalling, should be made available in order to be able to predict the vibrating characteristic of the blading with greater accuracy.

From author's summary

6049. Aggarwal, R. R., Oscillating aerofoil in compressible subsonic flow, *J. Sci. Engng. Res., India* **3,** 2, 377–384, July 1959.

The paper presents a review of the work on two-dimensional and three-dimensional oscillating airfoil theory in the case of compressible subsonic flow. Starting with Euler's equations, the

fundamental equations in the theory have been established. Various steps leading to the calculation of two-dimensional aerodynamic derivatives have also been given.

From author's summary

6050. Landahl, M. T., Aerodynamic derivatives for oscillating three-dimensional wings in transonic flow, Advances in Aeronautical Sciences, Vol. 1 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958), Pergamon Press, 1959, 255–275.

Article presents method of calculating generalized aerodynamic forces utilizing linearized theory. Although this theory is not applicable to steady transonic flow because of accumulation of disturbances moving slowly with respect to flow, it is usually applicable if flow oscillates with "reduced" frequency not less than $1 - M_L$ (M_L = local Mach number). Three-dimensional effects, important in transonic flow, are covered. Results for several different cases, and comparison with two-dimensional treatment, are included. For rectangular wing solution is series of which first term is solution for wing of infinite span; series convergence is usually sufficient after only three terms. Results here given should be of interest to those concerned with flutter or other airplane wing aerodynamic disturbances, but linearized theory may not be adequate for oscillating control surface, either because reduced frequency (based on control surface chord) is not high enough to satisfy criterion or because of occurrence of shock wave, with "buzz," ahead of surface.

C. W. Smith, USA

6051. Heskestad, G., and Olberts, D. R., Influence of trailing edge geometry on hydraulic-turbine-blade vibration resulting from vortex excitation, *ASME Trans.* **82** A (*J. Engng. Power*), 2, 103–110, Apr. 1960.

A study was made to determine effects of trailing-edge geometry on the vortex-induced vibrations of a model blade designed to simulate the conditions at the trailing edge of a hydraulic-turbine blade. For the type of trailing-edge flow encountered, characterized by a thick boundary layer relative to the blade thickness, the vortex-shedding frequency could not be represented by any modification of the Strouhal formula. The amplitude of the induced vibrations increased with the strength of a vortex in the von Karman vortex street of the wake; one exception was provided by a grooved edge, which is discussed in some detail. For a particular approach velocity, the vortex strength is primarily a function of the ratio of distance between separation points to boundary-layer thickness, the degree of "shielding" between regions of vortex growth, and frequency of vortex shedding.

From authors' summary

Aeronautics

(See Revs. 5587, 5590, 5591, 5599, 5832, 5871, 5872, 5882)

Astronautics

(See also Revs. 5549, 5563, 5587, 5832, 5932, 6019)

6052. Chapman, D. R., An approximate analytical method for studying entry into planetary atmospheres, NASA TR R-11, 44 pp., 1959.

A single, ordinary, nonlinear equation of second order is developed for entry of a vehicle into a planetary atmosphere. The equation includes terms representing the gravity force, the centrifugal acceleration and the lift force. The analysis is based on the assumptions that (1) atmosphere and planet are spherically symmetric, (2) the atmosphere is "locally exponential," and (3) peripheral velocity of planet is negligible compared to the velocity of the entering vehicle. These assumptions are very reasonable for Mars, Earth, and Venus, but may result in significant error if applied to Jupiter and Saturn. Two mathematical approximations are made. There are (a) "In a given increment of time, the fractional change of distance from the planet center, dr/r, is small compared to the fractional change in velocity, du/u" and, (b) "For lifting vehicles the flight path angle ϕ relative to the local horizontal direction is sufficiently small that the component of lift in the horizontal direction is small compared to the component of drag; that is $|(L/D)\tan\phi| \ll 1$." As a result of these assumptions the Chapman solution would be reasonable below an altitude where the drag has reduced the vehicle velocity to about 0.01 of the initial velocity. The author suggests using orbit-type calculations above this altitude. Ballistic, decaying orbit, entry from deflected orbit, glide, skip, and atmospheric braking trajectories are considered, from the point of view of the shape of the trajectory, maximum deceleration and peak heating. The analysis uses simple mathematics and is in general clear and easily understandable by anyone having a technical background. Graphical solutions of the equations are worked out for the various entries considered. Differences between the Chapman analysis and exact numerical machine calculations were shown to be in the order of a few per cent. In general, the report presents a good engineering analysis useful for estimating entry conditions into planetary atmospheres.

I. J. Eberstein, USA

6053. Edwards, R. H., and Campbell, G. S., Prediction of peak temperature for satellite entries with lift, *ARS J.* **30,** 5, 496–498 (Tech. Notes), May 1960.

Paper is an extension of analysis by Eggers, et al, [AMR **12** (1959), Rev. 1581] on trajectory of first skip into atmosphere of a lifting satellite. Higher-order terms are derived for peak vehicle temperature, maximum altitude, and velocity loss as functions of reentry angle. Comparison with more exact numerical results shows marked improvement at small entry angles over original work, as might be expected.

W. C. Griffith, USA

6054. Becker, J. V., Heating penalty associated with modulated entry into earth's atmosphere, *ARS J.* **30,** 5, 504–505 (Tech. Notes), May 1960.

Maximum deceleration during reentry of a satellite can be reduced using variable lift and drag as shown by Lees, et al [AMR **13**(1960), Rev. 2415]. Author shows that total vehicle heating which results from using variable lift and drag can be used to reduce peak deceleration or to obtain a wider guidance corridor prior to atmospheric entry. He concludes "that modulated entries, properly executed, will not involve prohibitive heating penalties."

W. C. Griffith, USA

6055. Phillips, R. L., and Cohen, C. B., Use of drag modulation to reduce deceleration loads during atmospheric entry, *ARS J.* **29,** 6, 414–422, June 1959.

Analysis is made of effect of discrete and continuous variations of drag of a vehicle entering the earth's atmosphere. The use of continuous drag modulation can reduce the deceleration loads by as much as 50 per cent, without significantly affecting the total aerodynamic heating of the vehicle. The approximate analysis is checked by numerical solutions of the complete equations of motion. Several specific applications of drag modulation have been considered, such as to a vehicle returning from the moon. Effects of lift modulation, which may be greater than those of drag modulation, are not considered in this paper.

W. H. Phillips, USA

6056. de Moraes, A., Effects of the earth's oblateness on the orbit of an artificial satellite: Part I, First order effects, *Anais Acad. Brasileira Cienc.* **30,** 4, 465–510, 1958.

Expressions are derived for first-order perturbations, due to oblateness, on the following orbital elements: radial distance, line of nodes, inclination, and right ascension. Results are compared with satellite observations.

Expressions are also derived for second-order perturbations, due to oblateness, on right ascension and radial distance, in an equatorial orbit only. Effects on right ascension would be measurable and could be used to improve geodesic knowledge.

Equations are studied which show that relativistic effects produce a displacement of the perigee which is in the same order of magnitude as that produced by third-order oblateness. Therefore geodesic knowledge must be improved before satellite observations can be used to check relativity theory.

C. D. Pengelley, USA

The *Aero/Space Engng.* 19, 5, May 1960 issue is designated as **Manned space stations issue.** Revs. 6057–6081 inclusive give titles and a few summaries of the articles included in the issue:

6057. Gilruth, R. R., and Strass, H. K., Manned space flight—present and future steps, 16–17, 88.

6058. Smith, L. B., The military test space station, 18–19.

6059. Hall, E. W., and Schwenk, F. C., Current trends in large booster developments, 20–21.

Manned flights will occur on Centaur and Saturn boosters that use high-energy propellants in upper stages. Although first launchings of these vehicles will occur in 1961 and 1963, the date that they become reliable enough for manned flights can be learned only through experience. From authors' summary

6060. Gazley, C., Jr., Atmospheric entry of manned vehicles, 22–23, 90.

It is concluded that there are two types of feasible vehicles for manned entry: (1) A blunt dense vehicle with little or no aerodynamic lift and a low-temperature ablation-cooling system. (2) A radiation-cooled vehicle using a very light drag brake or lifting surface to achieve high-altitude deceleration.

From author's summary

6061. Koelle, H. H., Engler, E. E., and Massey, J. W., Design criteria and their application to economical manned satellites, 24–25, 90.

By 1965 and no later than 1972, a one-piece manned satellite laboratory will be operating in space. It will have orbit selection and control, minimum assembly and checkout in space, crew-engineering and life-support systems, power generation and power systems, "lifeboat" capsule and rescue equipment, as well as logistic support. From authors' summary

6062. Stoiko, M., Kayten, G. G., and Dorsey, J. W., Manned scientific orbital laboratory, 26–27, 92.

The MSOL, which is intended to function both as a monitored scientific laboratory and as a test vehicle, is discussed with reference to design considerations, description of the vehicle, and performance. From authors' summary

6063. Doss, J. H., and Montague, L. J., Some factors influencing the selection of a manned space station concept, 28–29, 94.

The consequences of growth potential, flexibility, confidence, and influence of other space programs are among the factors discussed in this analysis of the merits of earth-constructed and orbit-constructed space stations.

From authors' summary

6064. Kramer, S. B., and Byers, R. A., A modular concept for a multimanned space station, 30–31, 90.

6065. Kaechele, L. E., and Olshaker, A. E., Meteoroids—implications for the design of space structures, 44–45, 98.

6066. Dow, N. F., The ionizing radiation in space—structural implications, 46–47, 98.

6067. Carter, J. W., and Bogema, B. L., Inflatable manned orbital vehicles, 48–49, 99.

6068. Coale, C. W., The role of damping in space structures, 50–51.

6069. Glaser, P. E., Thermal control of space vehicles—structural approach, 52–53, 99.

6070. Cooley, W. C., A comparison of nuclear and solar power systems for manned space stations, 54–55, 100.

6071. Del Duca, M. G., Babinsky, A. D., and Miraldi, F. D., Integrated thermodynamic systems for manned space stations, 56–57, 104.

6072. Ranken, W. A., and Frank, T. G., Utilization of plasma-cell energy conversion in nuclear reactors, 58–59.

6073. Carliss, W. R., A circulating dust-fueled, radiation-cooled space power reactor, 60–61.

6074. Howard, H. J., and Laughlin, R. M., The use of chemical power systems in the construction, servicing, and operation of manned space stations, 62–63.

6075. Haeussermann, W., Comparison of some actuation methods for attitude control of space vehicles, 64–65.

6076. Chatkoff, M. L., and Lynch, L. G., Attitude control of a space vehicle by a gyroscopic reference unit, 66–67.

6077. Stalony-Dobrzanski, J., and Imai, O., Attitude and flight path control system for a space station supply vehicle, 68–69, 100.

6078. Steinhoff, E. A., Orbital rendezvous and guidance, 70–71, 103.

"Let's meet on your perigee. I'll go into parking orbit and descend for final rendezvous. See you in constellation."

From author's summary

6079. Petersen, N. V., and Swanson, R. S., Rendezvous in space—effects of launch conditions, 72–73, 106.

Deep-space explorations can be carried out in the near future if a rendezvous capability is developed that can assemble, transfer personnel, and supply and maintain both scientific and military space stations. Rendezvous operation problems are minimized for equatorial launch bases. The use of a "quasi-optimum rendezvous guidance system" concept and of "rendezvous-compatible-orbits" makes rendezvous operations practical from existing intermediate latitude launch bases. From authors' summary

6080. Garber, T. B., Ascent guidance for a satellite rendezvous, 74–75, 108.

In practice, the residual errors in position and velocity at the end of the ascent phase serve as the initial conditions for a terminal guidance period during which the vehicle is brought into proximity with the satellite. From author's summary

6081. Felleman, P. G., and Sears, N. E., Jr., A guidance technique for achieving rendezvous, 76–77.

A guidance concept is presented for the terminal phase of space station rendezvous mission. Minimum fuel expenditure and control during the transfer maneuver are considered.

From authors' summary

End of Symposium

Ballistics, Explosions

(See Revs. 6003, 6005, 6036, 6056)

Acoustics

(See also Revs. 5573, 5694, 5794, 5810, 5867, 5887, 5904, 6004, 6041)

6082. Williams, A. O., Jr., Some effects of velocity structure on low-frequency propagation in shallow water, *J. Acoust. Soc. Amer.* **32,** 3, 363–371, Mar. 1960.

In order to analyze the effects of downward or upward refraction of small frequencies in shallow water, a first-order perturbation theory is applied to the known solutions for isovelocity water. Using a similar method to the case known as the square potential in quantum mechanics, the wave equation is solved following Pekeris' method. The eigenvalues of the equation are then determined for several modes and a function $S(\xi)$ is calculated using the fact that in quantum mechanics the combined set of modes form a complete orthonormal set.

The perturbation treatment is then applied to the nonisovelocity case and it is shown that the phase velocity v_n of the mode decreases as a result of the perturbation. The limitations of perturbation method are reviewed. A variation calculation applied to the same problem shows results to be in agreement with those obtained from the perturbation method. Comparison with field data agrees in showing an increased attenuation with downward refraction and the method appears to be applicable for a ratio of the depth to the acoustic wavelength varying between 2 and 4.

G. E. Jarlan, Canada

6083. Doak, P. E., Acoustic radiation from a turbulent fluid containing foreign bodies, *Proc. Roy. Soc. Lond.* (*A*) **254,** 1276, 129–145, Jan. 1960.

Title problem is formally solved using method of Green's functions. Treatment differs from that of reviewer [AMR **9**(1956), Rev. 1293] in choice of Green's function, and in working in terms of pressure rather than density. Author shows that good approximation to radiated sound is obtainable from knowledge of pressure fluctuations on the wall, and calculates "dipole" radiation from plane turbulent boundary layer. N. Curle, England

6084. Sakharova, M. P., Asymptotic representation of the sound field of a point source in a wedge-shaped region, *Soviet Phys.-Acoustics* **5,** 2, 214–219, Nov. 1959. (Translation of *Akust. Zh., USSR* **5,** 2, 215–220, Apr./June 1959 by the Amer. Inst. Phys., Inc., New York, N. Y.)

6085. Kanevskii, I. N., Analysis of the diffraction of a converging cylindrical wave by a sphere, *Soviet Phys.-Acoustics* **5,** 3, 300–307, Feb. 1960. (Translation of *Akust. Zh., USSR* **5,** 3, 294–300, July/Sept. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

An infinite cylindrical sound wave of given flare angle is incident on a rigid sphere on its axis. Incident and scattered potentials are given in infinite series of spherical functions. At large distances from the sphere an asymptotic representation is given for the scattered wave. The dependence on flare angle of the scattered intensity, total scattered power, scattering cross section and periodic force on the sphere are shown. The case of a sphere small in comparison with sonic wavelength is treated as a special case. W. W. Soroka, USA

6086. Kanevskii, I. N., Analysis of the diffraction of a converging cylindrical wave by a cylinder, *Soviet-Phys.-Acoustics* **5,** 2, 152–157, Nov. 1959. (Translation of *Akust. Zh., USSR* **5,** 2, 151–156, Apr./June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Author considers the diffraction of a converging cylindrical wave by an infinite cylinder situated coaxially with the wave front. The total potential is first calculated for the case of a perfectly rigid cylindrical obstacle and the radial component of the velocity is expressed in the form of a Fourier series. The potential of the reflected wave is then obtained where for great distances from the obstacle the asymptotic representation of the Hankel function is applied. The intensity of the incident converging wave is calculated approximately, and the ratio of the intensity of the scattered wave to the intensity of the incident wave is derived for cylindrical and for plane waves. A polar diagram indicates that the intensity of the scattered wave varies as a function of the flare angle of the cylindrical front and of the polar coordinates of the point of observation. This intensity increases monotonically with increasing flare angle in the direction of 180° and 90°, and is maximum for a flare angle of 75° in the direction 0°. G. E. Jarlan, Canada

6087. Lyon, R. H., On the diffusion of sound waves in a turbulent atmosphere, *J. Acoust. Soc. Amer.* **31,** 9, 1176–1182, Sept. 1959.

The directional and frequency diffusion of a plane monochromatic sound wave in statistically homogeneous, isotropic, and stationary turbulence is analyzed theoretically. The treatment is based on the diffusion equation for the energy density of sound waves, using the scattering cross section derived by Kraichnan [*J. Acoust. Soc. Amer.* **25,** p. 1096, 1953]....

A form for the frequency wave number spectrum of the turbulence is adopted which contains some pertinent parameters of the flow.... It is expected that the assumed spectrum is unrealistic at larger wave numbers. A new approach to the evaluation of the characteristic period of the flow is suggested. This spectrum is then related to the scattering cross section.

Finally, a diffusion equation is derived as a small-angle scattering approximation to the rigorous transport equation. The rate of spread of the incident wave in frequency and direction is calculated as well as the power spectrum and autocorrelation functions for the wave.

From author's summary by I. Dyer, USA

6088. Ingard, U., Attenuation and regeneration of sound in ducts and jet diffusers, *J. Acoust. Soc. Amer.* **31,** 9, 1202–1212, Sept. 1959.

The effect of noise regeneration by fluid flow on the performance of noise-attenuating structures is examined with special attention to muffler design. The insertion loss of a single element, as well as a continuous distribution of attenuating and noise-regenerating elements, is studied. An analysis of experimental data on jet noise indicates that the power spectrum of a circular jet depends

on frequency f and Mach number M approximately as $f^2 M^5$ at low frequencies, as $f^{-2.5} M^{9.5}$ at high frequencies, and as M^7 at the peak frequency. In terms of the corresponding jet spectrum, for which an empirical analytical expression is given, the maximum attainable insertion loss of a jet muffler diffuser is presented as a function of frequency. The deviation of the characteristics of a "lossy" diffuser from this upper limit depends on the attenuation and regeneration characteristics of the acoustical elements in the muffler. These characteristics are investigated for the special element consisting of a perforated sheet, and the results are applied to an analysis of the insertion loss of a muffler diffuser of the perforated basket type.

From author's summary by P. Rudnick, USA

6089. Masterov, E. P., Sound channel propagation in laminar-inhomogeneous media, *Soviet Phys.-Acoustics* **5,** 3, 339–343, Feb. 1960. (Translation of *Akust. Zh., USSR* **5,** 3, 332–336, July/Sept. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Assuming index of refraction to vary according to $n^2 = p^2 + (1 - p^2 + q)\exp(-az) - q\exp(-2az)$ and harmonic time-dependence, a formal solution for a point source in a half space is given as a contour integral containing Whittaker and Hankel functions. An asymptotic (large distance from source) development in terms of normal modes is given for the special case of an entire space (source infinitely removed from boundary of half space).

J. W. Miles, USA

6090. Arkhangel'skii, M. E., Action of sound on the process of diffusion from a liquid to a gel, *Soviet Phys.-Acoustics* **5,** 3, 370–372 (Letters to the editor), Feb. 1960. (Translation of *Akust. Zh., USSR* **5,** 3, 363–364, July/Sept. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

6091. Clarkson, B. L., The effect of jet noise on aircraft structures, *Aero. Quart.* **10,** 2, 103–126, May 1959.

Author provides a review of present knowledge of structural fatigue failure due to jet noise. Linear response theory of structures, noise pressure field characteristics of jet sources, and fatigue life estimations are discussed. Author concludes that it is currently possible to make reasonable estimates of stresses in structures due to jet noise, but the resultant fatigue life cannot be adequately estimated. The response theory described makes use of an assumed relation between panel stress and panel displacement, a quantity which may not be known for practical cases. Author considers damping such as internal hysteresis, joint slip losses, and acoustic radiation losses as possible life-increasing measures. He does not consider the possible concomitant increase in structural response when acoustic radiation losses are increased.

Review is limited to linear response theory, in part because the author believes that nonlinearity may not be of great importance in practical structures. Influence on fatigue life of simultaneous excitation in many structural modes (which gives rise to stress interaction effects) is not discussed. Also the problem of exceeding the ultimate stress by a small but finite probability of large stresses in the random response is not considered. Reviewer believes that the author has nicely surveyed present knowledge in spite of some of the limitations noted. I. Dyer, USA

6092. Howes, W. L., Ground reflection of jet noise, NASA TR R-35, 29 pp., 1959.

See AMR **11**(1958), Rev. 5200.

6093. Kleiman, Ya. Z., Special cases in the motion of two-component mixtures, *Soviet Phys.-Acoustics* **5,** 3, 308–319, Feb. 1960 (Translation of *Akust. Zh., USSR* **5,** 3, 301–313, July/Sept. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Certain cases of the nonstationary motion of a two-component mixture in the acoustic approximation are investigated, taking into account the friction between components, outflow of the mixture from a tube, propagation in the mixture of a disturbance arising at the interface between the media, disruptions in the mixture. As an illustration, the results of some numerical calculations are given for water-saturated sand.

From author's summary by K. Stewartson, England

Micromeritics

(See also Revs. 5572, 5739, 5805, 5989, 6029, 6110)

6094. Fritz, W., Experimental determination of particle sizes and a graphical representation of the size distribution according to Rosin, Rammler and Sperling, Chemiker Zeitung **83,** 24, 819-824, 1959.

The technical behavior of a multitude of particles is determined not only by its chemical constitution but also, to a great extent, by the grain-size distribution of its constituent particles. This is represented mostly by the summation curve of the sieving remainder; it plays an important part in engineering processes such as sieving, sifting, centrifuging, settling, flotation, etc., in the design calculation of filtering plants, and calculation of pressure loss of flow through porous goods. It influences the density and strength properties of sintered metals, briquets, ceramics, concrete.

Concepts of grain-size analysis are explained, such as effective diameter, i.e., the diameter of a sphere having the same volume as the grain, or the mean value of significant length dimensions of the particle. Also definitions of grain size based on some physical separating process, e.g., falling velocity, are given. Procedures of grain-size analysis are discussed in detail, such as: sampling, sieving (influence of time-duration, shape of grain, agglomeration, loading of sieve, and type of sieving machine), a sifting or winnowing in an air stream, separation in a liquid stream, sedimentation in a stationary liquid and its error sources; all these processes are critically evaluated. Representation of grain-size distribution in the Rosin-Rammler-Sperling chart (adopted by the German Industry Standards as DIN 4190), based on a two-parameter exponential function, is explained; its range of validity and its limitations are discussed. Author points out that for a statistical definition of grain goods only two parameters do not appear to be sufficient.

This is a clearly written exposition of the problems of statistical description of grain goods, of the various procedures for obtaining data for the grain-size distribution, and of its mathematical and graphical representation.

K. J. DeJuhasz, USA

6095. Keneman, F. E., Zalogin, N. G., Vorobyev, V. N., and Antoshina, O. S., The mechanism of efflux of granular bodies, Part 1 (in Russian), *Inzhenerno-Fizicheskii Zh.* **3,** 3, 69-73, Mar. 1960.

The mechanism of free efflux of granular materials through orifices is investigated. During efflux the moving part of the material has the form of an inverted truncated cone whose opening angle depends largely on the dimensions of the particles. Curves of pressure on the bottom of the vessel versus height of a column of the granular material are obtained and it is shown that the latter has no effect on the volume velocity of the granular material if it is not less than 0.5 ÷ 0.7 part of the diameter of the opening. This fact can be explained by the presence above the opening of a "dynamic arch" extending for a height of the order of the diameter of the opening. The character of particle movement over

the dynamic zone has no effect on the volume velocity of the granular material, i.e., almost all resistance to its movement arises on the surface of the dynamic arch.

From authors' summary

6096. Zalogin, N. G., Keneman, F. E., and Vorobyev, V. N., The mechanism of free efflux of granular bodies, Part 2 (in Russian), *Inzhenerno-Fizicheskii Zh.* **3,** 4, 18-22, Apr. 1960.

Neither the configuration of the bottom nor the slope of the walls of a bin has any effect upon the velocity of free efflux of a granular body. The velocity depends only on the angle of slope of the walls directly adjacent to the outlet orifice, lying in the zone of the dynamic arch. The dynamic arch is not more than one diameter of the orifice in height.

Only the angle of inclination of the walls, the relative diameter of the orifice opening, and the relative diameter of the bin have any effect on the velocity of efflux of a granular body. The height of the column of a granular body over the orifice has no effect on the velocity if it exceeds the diameter of the orifice.

From authors' summary

6097. Fay, C., Determination of the pressure drop necessary for the ventilation of grain with aid of reduced scale models (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **25,** 3-4, 309-320, 1959.

Resistance of air flow through grain storage at low Reynolds numbers follows the laws of laminar flow. Author proved this in a grain silo and checked it on a model in laboratory. Both results were in good agreement with theory. Air resistance can also be investigated in a potential tank by electric analogy. Purpose of this study was to detect location of insufficient ventilation within a grain silo.

S. Kolupaila, USA

6098. Lee, Y., Flow of coal in hoppers, *Combustion* **31,** 7, 20-27, Jan. 1960.

The motion is analyzed as an equilibrium between the weight of the coal and the wall friction plus the internal friction of the coal due to deformation. This last term is introduced as being proportional to the fractional change of the cross section in direction of the flow. It is shown that this term becomes extremely large in conventional hoppers near the discharge opening and explains clogging. A hyperbolic shape for the hopper walls avoids this high local resistance. This shape is defined and a design is given, a prototype of which was found not to clog.

H. A. Einstein, USA

6099. Lebedinskii, V. G., and Platonov, P. N., Character of the motion of a granular flow when flowing past bodies of different geometrical forms (in Russian), *Trudi Odessk. Tekhnol. In-ta Im. I. V. Stalina* **9,** 101-106, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6524.

Results are given for the experimental investigation of the character of the motion of a flow of a granular medium in a vessel when it is passing round bodies of different shapes; recommendations are made for the selection of rational forms for the transverse section of the bodies being flown past; the case is also examined of the flow around a number of bodies forming a plane and a three-dimensional grid.

From authors' summary

Courtesy Referativnyi Zhurnal, USSR

6100. Fay, J. W. J., and Ashford, J. R., Size distribution of airborne dust samples from British coalmines, *Brit. J. Appl. Phys.* **11,** 1, 1-13, Jan. 1960.

This paper is concerned with the size-distribution analysis of samples of airborne dust from British coal mines, taken with the thermal precipitator and evaluated using the optical microscope. It is shown that many of the particles of less than 1 μ in diameter present underground are probably associated with atmospheric pollution, and do not arise directly from mining operations. Consideration is then given to the size distribution of the above-1 μ component of the dust. The results recorded on special samples by the Pneumoconiosis Field Research Unit, together with some published size-analyses of airborne dust in British and South African mines, are examined, and it is shown that a single-component exponential distribution provides a reasonably good fit to the observed data. The size distributions reported during routine sampling work at the 26 collieries associated with the research are then analyzed in terms of the exponential distribution. It appears that within any given colliery there is no considerable variation in size distribution between facework on the coal-getting and preparation shifts and non-facework underground, although there is a suggestion that the airborne dust encountered in hard headings may contain a higher proportion of smaller particles than in other parts of the same colliery. There are, however, marked variations from coalfield to coalfield, the coarsest dust being reported in South Wales and the finest in Scotland. The implications of these results are discussed and it is shown that the 1-5 μ particle number count is a satisfactory parameter for the measurement of the hazard associated with airborne dust.

From authors' summary

6101. Ashford, J. R., Some statistical aspects of dust counting, *Brit. J. Appl. Phys.* **11,** 1, 13-21, Jan. 1960.

This paper is concerned with the application of statistical methods to the problem of evaluating samples of airborne dust obtained with the thermal precipitator. A brief description is given of the nature of the dust sample, followed by an outline of the techniques employed to estimate the number of particles deposited. The three main sources of counting variation—systematic differences between observers, basic counting error and random distribution of particles in the dust deposit—are then considered. The effect of size distribution on counting errors is examined and it is shown that this factor may lead to appreciable variation in the recorded counts. Following a short description of various properties of the dust deposit which, although not strictly associated with the counting process, have a bearing on the reported concentration, recommendations are made about optimum procedures for counting thermal-precipitator samples.

From author's summary

6102. Torobin, L. B., and Gauvin, W. H., Fundamental aspects of solids-gas flow: Part 1, Introductory concepts and idealized sphere motion in viscous regime; Part 2, The sphere wake in steady laminar fluids, *Canad. J. Chem. Engng.* **37,** 4, 129-141, Aug. 1959; **37,** 5, 167-176, Oct. 1959.

This is an analytical survey of literature on the subject of gas flow with introductory treatment of particle motion. The title used is not explanatory, using a coined expression "solids-gas flow" which does not convey directly the type of motion of loose solids particles carried by a gas flow of a fluid type. The publication deals rather with a flow through pipes and not with a flow in general. The exemplary range of processes in which particles in gas systems play an important role like dissemination of pollen and rocket flight seems to be incomparable. Reviewer suggests the following title: "Gas flow through pipes as a carrier of larger particles of solids."

The treatment of the problem of larger spheres in a gas flow would be more effective by an approach to the whole flow aspect from the balance and equilibrium point of view. Authors seem to have in mind readers familiar with the practical side of the problem, but who would appreciate having more theoretical background. It should be commented that all known classic equations like Navier-Stokes, Euler's and Bernoulli's are well supported by bib-

liographical quotations. It seems better to quote references in text and to avoid quoting them at subchapter headings.

Part II of the publication mentions Newtonian equation for drag of a sphere. Reviewer believes it useful and feels that the premises on which Newton based his theory would probably support the arguments used and that they should be explained in detail. The relationship between drag of spheres and the Reynolds number within the region of flows considered is well and correctly discussed, but the study of the region of the sphere's wake which occupies most of the part II seems to be not in proportion to the whole set up of the problem.

Conclusion: As the purpose of this series of articles is to present a critical analysis of the more significant studies concerned with the various individual phenomena of multiparticle solids-gas flow, it can be said that authors have achieved this purpose to a considerable extent. Nevertheless the treatment of the subject is not complete.

A. Scibor-Rylski, England

6103. Gasparyan, A. M., and Ikaryan, N. S., On the constrained fall of particles without shape (in Russian), *Dokladf Akad. Nauk ArmSSR* **26,** 2, 95-101, 1958; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1626.

Authors established by experiment that the relation of velocities of a constricted fall of nonspherical particles U and of spherical particles C, other conditions being equal, is not a constant magnitude equal to the coefficient of form Ψ^x as has been assumed by a number of authors. Starting from the assumption that the particle covers itself with a fixed layer of liquid, the linkage between U and C is determined in the form

$$\frac{U}{C} = \alpha^{-1/3}\left(\frac{1-\alpha\varphi}{1-\varphi}\right)^n$$

where α is the relation of the volume of the particle jointly with the liquid surrounding it to the volume of the equivalent sphere, φ the volumetric concentration of the particles, n the experimental coefficient. The results of the experiment agree satisfactorily with the calculations made with the formula. Relations were found for the velocities of the constricted fall of strictly spherical monodispersion particles within the limits of changes of porosity m from 0.5 to 0.9.

U. Ts. Andres

Courtesy Referativnyi Zhurnal, USSR

6104. Zabrodskyi, S. S., The coefficient of resistance (drag coefficient) of a solid particle in a flow of gas (in Belorussian), *Vestsi Akad. Nauk BSSR Ser. Fiz.-Tekh. Nauk* no. 4, 39-50, 1956; *Ref. Zh. Mekh.* no. 8, 1958, Rev. 8982.

A critical analysis is presented of existing data on the drag coefficients of solid particles of different shapes (including spherical) suspended, or in semi-suspension, in a fluid flow. Author investigates the influence on the drag of the relative surface roughness of the particles and of impeded spin, and the particular features of the flow around a group of particles, as well as a number of other questions. The drag coefficient of a particle C and the drag coefficient of an equivalent sphere C_{sph} are associated by the relationship

$$C = \xi C_{sph},$$

wherein C_{sph} is the drag coefficient of the sphere, depending on the Reynolds number R; the coefficient ξ is determined by the shape of the particle and the number R. It is maintained that for particles of a form far from spherical the coefficient ξ varies from a value somewhat less than unity to a value of 2 to 3, with reference to the R number (the characteristic dimension is the equivalent particle diameter d). It is noted that the drag coefficient of the particles in the presence of constrained spin increases by comparison with spin in an unrestricted case. In the case of a boiling layer (a layer in the state of ebullition), this circumstance indicated that the ratio of the minimum rate of spin of a particle to the corresponding velocity in unrestricted space is approximately $0.1K^{0.115}$, wherein

$$K = d\sqrt[3]{\frac{4}{3}\frac{g}{\nu^2}\left[\frac{\gamma_M}{\gamma_\Gamma} - 1\right]}$$

In the above, ν is the coefficient of kinematic viscosity; g the gravitational constant, γ_M and γ_Γ the specific gravities of the substance of the particle (s) and the gas flow respectively. The opinion is expressed that, in view of the insignificant value of the drag coefficient of the particle at large values of R, even the smallest particles are not completely entrained by rapid turbulent pulsation.

G. E. Khudyakov

Courtesy Referativnyi Zhurnal, USSR

6105. Bovda, M. A., Influence of certain parameters of a centrifuge of the suspension type on its motion during running (in Russian), *Izv. Vyssb. Uchebn. Zavedenii. Pisbcb. Tekbnol.* no. 3, 107-109, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6036.

An analysis is made of the influence exerted by some of the parameters of a centrifuge of the suspension type with a constant mass on the emergence of the gyroscopic effect. Such centrifuges represent the case of a suspended centered symmetrical gyroscope and are (in fact) autovibrating mechanical systems. In the analysis the friction of the centrifuge round its supports is disregarded. The differential equations are derived in the Lagrangian form; their solution gives the equations for the nutation angle and the angular velocity of the centrifuge's own rotation in relation to the rotation moment of the transmission and the centrifuge's moment of inertia.

V. N. Geminov

Courtesy Referativnyi Zhurnal, USSR

6106. Mugele, R. A., Maximum stable droplets in dispersoids, *AIChE J.* **6,** 1, 3-8, Mar. 1960.

This is a condensed account of droplet size distributions, primarly in two-phase sprays. Introducing the concept of a maximum permissable drop size, the author shows that this can be used to correlate available data.

S. Corrsin, USA

6107. Sitkei, G., On the theory of jet atomization (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **25,** 1/2, 87-117, 1959.

In the present study the external and internal forces acting upon the liquid jet have been treated. It has been shown that the decomposition into drops of the jet is caused mainly by the intensive low-frequency turbulent pulsation acting as an internal force on the one hand, and the incidental dynamic power, arising on the front surface of the moving drops, as an external force on the other hand. By taking the above theory as a basis, relations of quantitative character have been deduced for the mean drop diameters.

The conditions of jet movement are discussed and, as a result, the author has succeeded in finding a characteristic function describing correctly the movement conditions of the jet as a function of various parameters. Finally, a method for an approximate determination of the fuel distribution is published.

From author's summary

Porous Media

(See also Revs. 5897, 5898, 5899, 5969, 6093)

6108. Happel, J., Viscous flow relative to arrays of cylinders, *AIChE J.* **5,** 2, 174-177, June 1959.

Author extends previous work which dealt with the steady slow motion of a fluid relative to spherical particles to the case of flow

through groups of cylinders. Two situations are considered; flow along and flow perpendicular to cylinder arrays. The basic notion involves the solution of the Navier-Stokes equation for creeping motion, maintaining the boundary condition of zero slip at the cylindrical boundary while an outer boundary which encloses only one of the cylinder sections (to form a cell) is maintained as a "free surface" (a surface of zero shearing stress). It is in effect assumed that the shape of the outer boundary has no effect on the motion. The relative volume of fluid to solid in the cell is taken to be the same as the relative volume of fluid to solid with assemblage of cylinders. By use of Darcy's equation for flow through a porous medium, author obtains expressions for the Kozeny constant for flow parallel to and perpendicular to cylinders. These values for various values of fractional void volume are compared to those for assemblages of spheres.

Agreement with experimental data is spotty, but author believes this may be due to the fact that information on fiber arrangement is not provided. Comparison with an exact theoretical solution by Emersleben for the flow parallel to uniform circular cylinders in a square array shows that the free-surface model is valid for dilute systems, as might be expected.

A discussion of the performance of the theory against experience with pressure drop through heat exchanger tube banks is given. It is concluded that the method provides a simple and uniform method for handling viscous flows through assemblages of cylinders which works reasonably well for random or uniform flows through fibrous materials and through banks of tubes in equilateral triangular arrangement, but it does not work well with square arrangement. It should be remembered that the free-surface model employed precludes a solution which reflects variations in tube arrangement. It can be expected that this simple theory will have further application to more complicated flows (such as those involving actual heat transfer) and may be useful in providing parameters for the correlation of data.

J. P. Breslin, USA

6109. Kovacs, G., The distribution of seepage flow under the downstream side of dams (in Hungarian), *Hidrôlogiai Kôzlöny* **39,** 3, 190–198, June 1959.

Based on electric analogy measurements and simplified mathematical derivations, author presents an approximate method for the calculation of discharge under flat dams with single sheetpile, and the distribution of seepage flow along the downstream side.

Reviewer believes that author's assumption regarding the downstream side as a constant potential line imposes unnatural boundaries on the flow domain. This is a very outmoded concept and can not be applied for the case investigated. For this reason application of electric analogy can not give reliable results. A set of solutions for different geometries using inverse relaxation process would have served the purpose. The oversimplified mathematical analysis seems unreasonable in view of the available powerful methods such as the Zhukovsky transformation, which would have given a simple but exact solution of the problem with proper boundary conditions.

A. L. Simon, USA

6110. Piskunov, N. S., Analysis of the work of lines of force wells which intersect and adjoin the contours (in Russian), *Trudî Vses. Neftegaz. N.-i. In-ta* no. 12, 103–119, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6544.

An investigation is carried out of the work of lines of force wells intersecting petroleum strata of uniform permeability. Questions are examined to decide when to treat wells designed as force wells more efficiently as exploitation wells; what part of the wells should be utilized as force wells and what part as exploitation wells; for what interval of time force wells should be used as exploitation wells; after what period of time after drilling for exploitation wells should drilling for force wells be begun and how this would affect the exploitation process. The investigation of these questions took place for a project in which the working of a five-row system of exploitation and force wells was concerned. In order to determine the yield of the wells a system of integral equations was obtained which is solvable by an approximate method based on the division of the exploitation period for the wells into separate intervals of time, during which the yields of the wells are assumed constant. A selection is made of the optimum variant from the point of view of the maximum separation of petroleum, based on the analysis and comparison of different variants of the exploitation of a five-row system of wells.

G. S. Salekhov

Courtesy Referativnyi Zhurnal, USSR

6111. Oroveanu, T., Approximation method for the investigation of the flow into wells in inhomogeneous porous media (in German), *Rev. Mĕcan. Appl.* **4,** 2, 279–300, 1959.

Paper treats the steady-state flow into a well, of a homogeneous, incompressible fluid in two dimensions which is contained in a porous m dium of inhomogeneous permeability. Gravity is neglected. The "approximation method" consists of approximating the real permeability variations by a special function, containing logarithms. The problem is then solved *exactly* for the approximated permeability variations. The method of attack is one of transformation of the basic differential equation into polar coordinates and expressing the solution in terms of a series expansion using orthogonal eigenfunctions.

A. E. Scheidegger, Canada

6112. Alikhashkin, Ya. I., Solution of the problem of an incomplete well by the method of straight lines (in Russian), *Vychislit. Matematika* no. 1, 136–152, 1957; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6539.

Investigations are carried out on an axially symmetrical pressurized inflow of an ideal incompressible liquid to an incomplete well in a homogeneous porous medium in a stratum of finite height (for the mathematical setting of the problem being investigated [see, for instance, the works of M. Masket "Motion of a homogeneous liquid in a porous medium," Izd-vo in.lit., 1949, and of I. A. Charno "Subterranean hydromechancis," Gostekhizdat, 1948]. The solution merges with the determination of the velocity potential $\Phi = \Phi(r, z)$ satisfying, in a rectangle $r_0 \leqslant r \leqslant R$, $0 \leqslant z \leqslant h$, the equation

$$\frac{\partial^2\Phi}{\partial r^2} + \frac{1}{r}\frac{\partial\Phi}{\partial r} + \frac{\partial^2\Phi}{\partial z^2} = 0 \qquad [1]$$

and the boundary conditions

$$\left(\frac{\partial\Phi}{\partial z}\right)_{z=0,\ z=h} = 0, \quad (\Phi)_{r=r_0} = 0 \quad (0 \leqslant z \leqslant h)$$
$$\left(\frac{\partial\Phi}{\partial r}\right)_{r=r_0} = 0 \quad (b \leqslant z \leqslant h), \quad (\Phi)_{r=R} = 1 \qquad [2]$$

In the present study the boundary problem [2] for Eq. [1] is solved by the straight line method, which was developed in M. G. Slobodyanskii's works [*Prikl. Mat. Mekh.* **3,** no. 1, 1939] and by V. N. Fadeev [*Trudî Mat. In-ta Akad. Nauk, SSSR* **27,** 1949]. As the result of using this method an approximate solution of the problem was obtained, giving the possibility of establishing the relation

$$\Phi = \Phi_k(r) = \Phi(r, z_k), \qquad (k = 1, \ldots, n-1)$$

along the straight line $z_k = \text{const}$, where n is the number of straight lines by which the given rectangle is split up into $n + 1$ strips. The solutions for $b = 1$, $r_0 = 0.01$, $R = 10$, $b = 0.25$, 0.50, 0.75 and $n = 8$ are given in a table, computed with an accuracy to

four decimal places. Curves are drawn for the relations of Φ and $\partial\Phi/\partial r$ to z for several values of r = const. It is shown that the results realized coincide practically with the results obtained by the author by another method [title source 1957, no. 1, 131–135]. The paper continues by producing an approximate solution (using the straight line method) for the problem on the inflow of an ideal incompressible liquid to an incomplete well in a homogeneous but double-layered porous medium for different values for the numbers $\alpha = k_2/k_1$, when k_1 and k_2 are the coefficients of permeability of the upper and lower layers. In this case the pressure $H = H(r, z)$ is taken for the function being sought. As was the case in the previous problem the solution is incorporated in a table and graphs are drawn for different values for r = const to show the relations of H and $\partial H/\partial r$ to z.

G. N. Pykhteev

Courtesy Referativnyi Zhurnal, USSR

6113. Pirverdyan, A. M., Babich, E. S., and Babich, Yu. A., An approximate method of calculation for the inflow of liquid into a battery of wells arranged in a circle when an elastic regime exists (in Russian), *Izv. Vyssh. Uchebn. Zavedenii Neft' i Gaz* no. 6, 55–60, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6543.

This is an investigation of a phase in the process occurring after the confluence of the eddies of depression, produced by every well in the battery, into a single spreading circular front. By making use of the known solution for a well situated in the center of a round stratum, taking the contour of radius R_c as representing the enlarged well, the authors ascertain the magnitude of the depression

$$\Delta p = \frac{\mu q}{4\pi kb} \log_e \left(1 + \frac{4\kappa Q}{R_c^2 q}\right) \qquad \left(Q = \int_0^t q(\tau)\, d\tau\right) \qquad [1]$$

where $\Delta p = p_k - p_c$ represent the depression, p_k, p_c the pressure on the feed contour and on the enlarged well, μ is the petroleum's viscosity, k the coefficient of permeability, b the size of the stratum, κ the coefficient of piezoconductivity, q the flow yield of all the wells in the battery, Q the total yield. The authors then proceed to approximate the logarithmic multiplier to [1] by means of the expression $a(4\kappa Q/R_c^2 q)^n$ and for the limits $1 < R_k/R_c < 10$ find values for $a = 1.13$ and $n = 0.32$. For arbitrary values for the parameters a and n the following dimensionless magnitudes are introduced

$$\bar{Q} = \frac{\mu Q}{2\pi kbt_0 \Delta p_0}, \qquad \bar{J}^{\frac{1}{1-n}} = \int_0^{\bar{t}} (\Delta \bar{p})^{\frac{1}{1-n}}\, d\bar{t}$$

$$\bar{\tau} = \frac{\kappa t}{R_c^2}, \qquad \Delta \bar{p} = \frac{\Delta p}{\Delta p_0}, \qquad \bar{t} = \frac{t}{t_0} \qquad [2]$$

Here t_0 is the initial moment of time corresponding to the confluence of the funnels of depression, Δp_0 being the depression with $t = t_0$. Equation [1] is reproduced in the form of

$$\frac{(1-n)^{n-1}}{2^{2n-1} \cdot a} \frac{1}{\bar{\tau}^n} = \frac{\bar{Q}}{\bar{t}^n \bar{J}} \qquad [3]$$

The relation

$$\bar{Q} = \frac{\bar{J}}{\bar{J}'} q \qquad [4]$$

is the result. An analysis is given for three cases of changes in $\Delta \bar{p}$

(1) $1 > \bar{t} > 0$, $\Delta \bar{p} = \bar{t}$, $\bar{t} > 1$, $\Delta \bar{p} = 1$

(2) $1 > \bar{t} > 0$, $\Delta \bar{p} = \bar{t}^2$, $\bar{t} > 1$, $\Delta \bar{p} = 1$

(3) $1 > \bar{t} > 0$, $\Delta \bar{p} = (\bar{t})^{0.5}$, $\bar{t} > 1$, $\Delta \bar{p} = 1$

and formulas are furnished for each case. The results of the numerical calculations, incorporated in a table, are compared with the results for the same solutions obtained on an electrointegrator EM-8 of the computational center of the Acad. Science of the Azerbian S.S.R., and also with the results worked out by I. A. Charno and V. N. Shchelkacheva. The results of the comparisons were satisfactory.

V. A. Karpychev

Courtesy Referativnyi Zhurnal, USSR

6114. Todd, D. K., and Huisman, L., Ground water flow in the Netherlands coastal dunes, *Proc. Amer. Soc. Civ. Engrs.* **85,** HY 7 (*J. Hydr. Div.*), 63–81, July 1959.

Authors give an approximate "Dupuit-Forchheimer" analysis of a steady fresh-water body, symmetrical with respect to a vertical plane and floating on static salt water. A horizontal, slightly permeable clay layer, situated below sea level, divides the fresh water body into a lens above and a much larger pocket below. Portions of the latter extend beyond the fresh-water lens ("tongues"). On both sides of the lens the clay layer is covered by a horizontal fresh – water and a salt + water layer, respectively. Mixing and capillary transition zones are neglected.

The steady flow within the fresh-water region is assumed to be horizontal everywhere, with planes of constant potential parallel to the vertical plane of symmetry. Potentials in lens and pocket satisfy the pressure conditions on the free surfaces. Across the clay layer a potential difference exists, giving rise to a vertical flow through this permeable wall, which is accounted for by corresponding terms in the continuity equations of the horizontal flow.

Authors start by calculating flow and shape of the "tongues," assuming constant flow potential in the region above the clay layer. This assumption would seem to contrast with the results of the following sections, which state that the flow per unit area in this region is of the same order of magnitude as the "tongue" flow itself.

After introducing several approximations expressions for flow and shape of the fresh-water body are established.

In reviewer's opinion the expressions for the shape of lens and pocket must be questioned, since they have been derived from "Dupuit-Forchheimer" assumptions which do not satisfy the kinematic boundary conditions.

No comparison with actual measurements is given.

G. Mandl, Netherlands

6115. Lyashko, I. I., Determination of the outlet velocities of filtration under a multichannelled dam situated over a curvilinear underground water-resistant stratum (in Russian), *Nauk. Zap. Kievsk In-ta* **16,** 2, 99–110, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1639.

The filtration is examined in the foundation of a dam with a thin multichannel apron and a thick two-channel apron, when there is in existence a horizontal subterranean water-resistant layer and where the channels are disposed in arbitrary fashion (with exception of the lower which is placed at the end of the apron). For a thin two-channel apron a study is also made of the case of a curvilinear water-resistant layer. The problems mentioned are solved by the method of major regions with the aid of variational principles. The variational theorems are used by the author not to fix the pressure on the dam but to fix the discharge under the dam. As the result of his investigations author obtains an upper and a lower estimate for the discharge and outlet velocity for the lower channel. The differences between these estimates for the special cases studied do not exceed 6% for the discharge and 10% for the outlet velocity (the case of the thick apron). For practical purposes this degree of accuracy is quite sufficient.

N. N. Verigin

Courtesy Referativnyi Zhurnal, USSR

6116. Guseinzade, M. A., and Govorova, G. L., Determination of the leakage of liquid when working strata under water-pressure (in Russian), *Neft. Kh-vo* no. 3, 57–58, 1958; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1646.

The problem is investigated on the determination of the motion of water from the peripheral portion of a stratum during the working of rings of exploitation and forcing batteries of wells in a petroleum field, the differences in viscosity of the water and the petroleum and their phasal permeability being disregarded. The calculation formula links up the leakage (under-flow) of liquid with the yield and the site pressure of the outer row of wells. Two cases are investigated, when the outer row is actually the row of wells being exploited or force-worked. An example is given of a numerical calculation. The calculation formula is recorded for rectilinear rows.

V. N. Nikolaevskii

Courtesy Referativnyi Zhurnal, USSR

6117. Shvidler, M. I., A spatial problem in the theory of filtration (The theory of inflow of the liquid to a well with a crack in the zone near the area being worked) (in Russian), *Trudî Ufimsk. Neft Nauk-i. In-ta* no. 2, 155–162, 1957; *Ref. Zh. Mekh.* no. 2, 1959, Rev. 1649.

The paper commences with an account of the results of numerical calculations, by means of formulas obtained previously by the author [*Izv. Akad. Nauk SSSR, Otd. Tekn. Nauk* no. 11, 42–49, 1955] dealing with the error involved in the magnitude of the lowered pressure at several points of a system being studied by him. The system represented a horizontal disk-shaped crack interacting with a cylindrical vertical well during filtration of a horizontal stratum of constant width. The author continues his paper by investigating the same problem to cover the case where the well with the crack drains a homogeneous anisotropic stratum. The solution for this case by means of the known method of the coordinate conversion merges with the problem for the isotropic stratum. The third part of the paper contains the expression for the pressure in every point of an infinitely extended horizontal stratum for the case where the filtration is being carried out in conditions of an elastic regime of filtration; here the known methods of operational calculations are brought into use.

V. P. Pilatovskii

Courtesy Referativnyi Zhurnal, USSR

6118. Maslov, N. N., The present state and some new principles in the filtration theory of dynamic stability of water-saturated soil in the foundations and slopes of installations (in Russian), *Sb. Trudî Leningrad Inzh. Stroit. In-ta* no. 28, 5–33, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6554.

A review is given of the work done by the department of "Bases and foundations" of the Leningrad engineering-constructional institute on the dynamic stability of water-saturated soils. Some concepts are advanced, on the strength of the results of laboratory and large-scale experiments, regarding the influence exerted on the dynamic stability of the sands by the power of the water-saturated layer, its overload, the period of dynamic reaction and some other factors. Corresponding general relationships are recommended for cohesive soils. Based on the above concepts some practical proposals are drawn up with the purpose of improving the dynamic stability of foundations and earth constructions. In particular a proposal is made to compact the water-logged earth masses by providing outlets for water and air by sinking shafts into them (needdle-filters)

V. M. Shestakov

Courtesy Referativnyi Zhurnal, USSR

6119. Trebin, F. A., Investigation on the filtration of heterogeneous systems and their utilization with the aid of hydrodynamical calculations for the working of petroleum-bearing areas (in Russian), 4th International Petroleum Congress, Gostoptekhizdat **3**, 431–442, 1956; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6563.

This communication was read at the petroleum congress held in Rome in 1955. A general survey is given of investigations carried out in the Soviet Union on the problems of filtration of heterogeneous liquids. The survey is preeminently of a descriptive nature. Information is given regarding the investigational character of the problem, the prerequisites for the solution of a number of problems relating to the petroleum stratum when a regime of dissolved gas is present and when the gassified petroleum is displaced by adjacent water, the investigation for taking into account, when effecting these solutions, the actual properties of petroleums, the examination of the possibilities of modelling the filtration of liquids other than single-phase and the general trend of studies dealing with the basic conditions of rational working of large petroleum fields of the platform type. Generally speaking, the paper deals with investigations carried out in the laboratories of the All-Soviet scientific research institute for petroleum.

V. A. Arkhangel'skii

Courtesy Referativnyi Zhurnal, USSR

6120. Sideras, Sh., The phenomenon of reduction of the water content of water-saturated sand slopes (in Russian), *Trudî Kannassk. Politekhn. In-ta* 9, 147–158, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6555.

Experiments are described on the dynamic stability of a model of a water-saturated earth bank, with a height of the order of 15 cm, to impact and vibration reactions. As the result of the experiments a qualitative picture was obtained of the character of the deformation of the bank.

V. M. Shestakov

Courtesy Referativnyi Zhurnal, USSR

6121. Scheidegger, A. E., On the stability of displacement fronts in porous media: A discussion of the Muskat-Aronofsky model, *Canad. J. Phys.* **38,** 153–162, Feb. 1960.

During the displacement of a fluid in a porous medium by another less viscous one, the displacement front may become unstable. The nature of this instability in the case of a sharp front (Muskat-Aronofsky model) is considered. It is shown that "fingering" will occur if the mobility ratio is less than unity, and that these fingers cannot be of arbitrary size. A more complete analysis of the nature of finger growth, taking account of the statistical properties of the porous medium, is promised.

R. E. Gibson, England

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 5545, 5568, 5699, 5705, 5736, 5805, 5808, 5809, 5892, 5904, 6009, 6056, 6082)

6122. Zatrutina, R. F. Mikhaylova, Z. M., and Silkin, B. I., (editors), International Geophysical Year bibliography of literature in the Russian language for 1958, NASA TT F–12, 75 pp., May 1960.

6123. Sangster, W. E., A method of representing the horizontal pressure force without reduction of station pressures to sea level, *J. Meteorol.* **17,** 2, 166–176, Apr. 1960.

Synoptic meteorologists have long realized that the procedure of reducing barometric pressure to sea level and drawing m.s.l. isobars is not satisfactory in mountainous areas and that geostrophic winds measured from m.s.l. isobars over high ground can be very misleading. The author defines a set of coordinate surfaces for use in synoptic meteorology, one of which follows the surface topography and on which the geostrophic wind is a better approximation to the true wind. Higher coordinate surfaces reflect the

topography in diminishing degree and become isobaric at 500mb. The transformation of the principle meteorological equations to these coordinates is thoroughly treated; the derivation of the geostrophic wind is illustrated by examples and comparison made with m.s.l. isobars. However, in reviewer's opinion, the complication of the new coordinate system is likely to outweigh any advantage to be gained from its use. J. S. Sawyer, England

6124. Rattray, M., Jr., On the coastal generation of internal tides, *Tellus* **12,** 1, 54–62, Feb. 1960.

Wave equations, boundary, and discontinuity conditions relating the internal tide to the surface tide in a two-layer system are derived. Solutions of these equations give internal tides which are comparable to the surface tide; i.e., in the coastal region these internal tides will behave as standing wave, whereas further offshore their nature will change to that of a progressive wave traveling seaward. H. Arakawa, Japan

6125. Caloi, P., The free oscillations of the Gulf of Civita Vecchia and the action of the kinematic viscosity (in Italian), *G. Gen. Civ.* **97,** 11, 907–917, Nov. 1959.

Calculations made on the basis of linearized ideal fluid theory show that the period of uninodal oscillations of the harbour of Civita Vecchia should have a period of 6 minutes. The value derived from observations is 10.8 minutes.

The reason for the difference is sought in the shallow depth of the harbour (mean depth 6 meters). The present paper makes allowance for the effect of viscosity and shows how this will alter the period. Viscosity increases the period; and with a coefficient of kinematic viscosity equal to 840 cgs units, agreement with the observed period is obtained. Results can be extended to higher harmonic oscillations. J. M. Jackson, Scotland

6126. Saint-Guily, B., The influence of Coriolis forces on sea currents (in French), *Houille Blanche* **14,** 5, 556–559, Aug. 1959.

Author first discusses the theories of Bjerknes, Helland-Hansen and Ekman which relate to the dynamics of the oceanic circulations and show the importance of the role played by Coriolis forces. By writing the hydrodynamic equations of motion in terms of six dimensionless numbers, author computes the numerical value of these parameters for three different examples. By comparing orders of magnitude, it is possible to estimate the relative effect of Coriolis forces in a given motion without resorting to integration of the equations of motion.

C. E. Carver, Jr., USA

6127. Reed, S. G., Jr., N-wave propagating into a stratified atmosphere, *Physics of Fluids* **3,** 1, p. 134 (Letters to the Editor), Jan./Feb. 1960.

Naval Architecture and Marine Engineering

(See also Revs. 5687, 5822, 6044)

6128. Schwanecke, H., Six component measurements on a V-shaped hydrofoil in symmetrical and nonsymmetrical flow (in German), *Schiffstechnik* **6,** 32, 93–106, June 1959.

The surface-piercing hydrofoil with semicircular section and straight rectangular planform is tested in the open-water section of a circulating water tunnel for a Reynolds number of 0.19×10^6 and a Froude number (referred to the draft) of about 2. The effective aspect ratio defined with respect to the angle of deadrise of 33 degrees was 4.77. After representing the well-defined systems of reference-axis, including schedules for transformation between these axes, complete results are given in diagrams for varying angles of trim, drift and heel. Observed cases of aeration are stated and some photographs are given. Comparison is made with former tests and some theoretical considerations. Satisfactory agreement leads to the statement of a method for calculating stability of a hydrodoil-craft on course and in turning. There are 12 references.

H. Thieme, Germany

6129. Nebesnov, V. I., Dynamics of a single-screw ship when being moored in narrow waters (in Russian), *Nauchno. Trudi Odessk. In-ta Inzh. Morsk. Flota* no. 16, 30–51, 1958; *Ref. Zh. Mekh.* no. 6, 1959, Rev. 6286.

A solution is proposed for the problem on the mutual connections between the separate parameters characterizing the behavior of the hull of a ship and the principal prime-mover when maneuvering (applicable to mooring in narrow waters) a single-screw ship by the so-called Dutch method (approach dead slow, bow first to the mooring and then turning by means of helm and propeller). The solution of two equations is considered to be the basis of the study: (1) the equation for the transition motion of the principal motor jointly with the screw propeller and (2) the equation of the turning motion of the ship about the vertical axis, transmitted through the point of contact between the end point of the bow of the ship and the mooring during the mooring process. The solution of the first equation gives the principle of the change of the angular velocity of the screw with time

$$\omega = \frac{\omega_0 \sqrt{ab} + b\,th\,\sqrt{ab}\,t}{\sqrt{ab} + a\,\omega_0\,th\,\sqrt{ab}\,t}$$

where ω_0 is the initial angular velocity of the screw, a and b are coefficients, t is time. The solution of the second equation gives the principle of the change of angular velocity of the turning of the hull

$$\theta = \left\{ C e^{\pm 2 c_1 (\varphi + \varepsilon)} - \frac{2A}{4 C_1^2 + 1} \times \right.$$
$$\left. \times \left[\cos(\varphi + \varepsilon) \pm 2 c_1 \sin(\varphi + \varepsilon) \right] + \frac{m}{c_1} \right\}^{1/2}$$

where φ is the angle between the plane of the diameter of the ship and the front of the mooring, read off the face of a watch, C is a constant integration, c_1 is the coefficient of resistance of the water to the turning motion, m is the specific moment due to the action of the screw on the hull of the ship (the rudder). The function $\theta = \theta(\varphi)$ enables the relation to be obtained, in every concrete case, between the angle of turn and the time t

$$t = \int_{\varphi_0}^{\varphi} \frac{1}{\theta(\varphi)}\, d\varphi$$

The equations described enable investigations to be carried out for various cases of turning the ship (the turning of a ship under the action of wind and current, the turning of a ship with the help of a motor, the turning of a ship under the action of wind and current with motor aid), and to apply them practically in graph form. The equations permit the following determinations to be made: (1) the moment of reaction of the screw propeller on the hull of the ship in functions of the angle of declination of the rudder and the number of revolutions of the motor, (2) the best combination of the angle of approach of the ship to the mooring, the regime of the work of the motor and the angle of declination of the rudder in different weather conditions, and also to solve other practical questions on mooring. S. I. Kozhushnyak

Courtesy Referativnyi Zhurnal, USSR

6130. Weinstein, I., Force investigation of three surface-piercing supercavitating hydrofoils with 45° negative dihedral, NASA TN D-378, 44 pp., June 1960.

Two triangular hydrofoils (with and without leading-edge sweep) and a rectangular hydrofoil were investigated. Of the two triangular hydrofoils, which had equal aspect ratios regardless of depth, the one with leading-edge sweep had somewhat better over-all lift-drag ratios. The maximum lift-drag ratio obtained with this hydrofoil was approximately 5.0. Complete ventilation occurred at angles of attack of 10° to 12° and above for all three hydrofoils. A brief comparison shows the experimental data to be in good agreement with that predicted by theory.

From author's summary

6131. Raghuram, T. S., and Nigam, S. D., Units, ships models and similitude, *J. Sci. Engng. Res., India* **3,** 2, 357–362, July 1959.

Friction, Lubrication and Wear

6132. Tao, L. N., A theory of lubrication with turbulent flow and its application to slider bearings, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 1–4, Mar. 1960.

Using Blasius' empirical resistance law and a fractional power velocity distribution, a governing equation is derived for turbulent flow hydrodynamic lubrication. With appropriate parameter values this equation is shown to reduce to Reynolds equation in three dimensions for laminar flow. Usual thin-film approximations are made, i.e., fluid is incompressible, flow is steady, and the author justifies the neglect of inertia terms when flow is turbulent. Author applies the general equation to the solution of the infinite slider bearing and derives expressions for load capacity, center of pressure, frictional force, and power loss. Slider-bearing characteristics with laminar flow are shown to be special cases of the previously derived expressions. A numerical example is presented which shows a flatter pressure profile for the turbulent case as compared with laminar flow. Center of pressure and load capacity are also compared.

D. F. Hays, USA

6133. Kotlyar, Ya. M., On one possibility of obtaining an exact integral of Reynolds equation in closed form, *Soviet Phys.–Doklady* **4,** 4, 761–764, Feb. 1960. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **127,** 1, 59–62, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

A solution to one form of Reynolds equation for hydrodynamic lubrication was obtained. Conditions imposed were the use of a narrow opening with fixed walls using slow steady barotropic flow and constant kinematic viscosity. By the use of the stream function and an approximation for the film thickness, the solution to the equation for pressure reduces to the solution of Laplace's equation. Boundary conditions are imposed and an equation for flow is derived.

H. G. Rylander, USA

6134. Tao, L. N., General solution of Reynolds equation for a journal bearing of finite width, *Quart. Appl. Math.* **17,** 2, 129–136, July 1959.

Author solves the Reynolds equation for an isoviscous lubricant in a journal bearing of finite width by using a series of Heun functions, which arise after an appropriate change in coordinates. This expansion admits new exactitude in the solution, at the expense of working with transcendental functions so rare that a study of convergence of power series for them is included. Expressions are developed for pressure distribution, load-carrying capacity, and coefficient of friction for a fully lubricated bearing. Cavitation is not considered, so the pressure function might be viewed better as a departure from some ambient high enough to prevent film rupture. Apart from the difficulty, it would seem desirable to include cavitation, as do the less exact treatments of Cameron and Wood [AMR **3**(1950), Rev. 2559] and Walther and Sassenfeld [AMR **8**(1955), Rev. 1234, including especially their Reference 6]. It may be noted also that consistency seems to require that L be defined as l/r instead of l/d.

This paper provides not only an exact solution to the particular problem studied, but also a fresh approach to the Reynolds equation which may help in solving other problems.

J. C. Bell, USA

6135. Toporov, Y. P., The question of the effect of moisture on the external friction of solid bodies (in Russian), *Inzhenerno-Fizicheskii Zh.* **3,** 4, 44–48, Apr. 1960.

The mechanical properties of a layer consisting of highly dispersed particles are mainly determined by its moisture. Therefore resistance to the relative displacement of contact surfaces between which this layer is situated depends essentially on the moisture in the surrounding atmosphere. Depending on the nature of the particles and the form of contact surfaces, the coefficient of static friction increases or decreases with a change in moisture.

From author's summary

6136. Presnyakov, A. A., and Vinnitskii, A. A., A device with a split block for the determination of the friction coefficient, *Indust. Lab.* **25,** 4, p. 505, Apr. 1960. (Translation of *Zavod. Lab., SSSR* **25,** 4, p. 487, Apr. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

6137. Levai, I., Computation of grease-lubricated plain bearings according to the hydrodynamic theory (in Hungarian), *Gép* **11,** 6, 237–243, June 1959.

Books Received for Review

AIGRAIN, P. R., COELHO, R. J., AND ASCARELLI, G., Electronic processes in solids, New York, John Wiley & Sons, Inc., 1960, x + 67 pp. $4.

ASTON, F. G., AND FRITZ, F. F., Thermodynamics and statistical thermodynamics, New York, John Wiley & Sons, Inc., 1959, xiv + 556 pp. $8.25.

BELLMAN, R., AND HALL, M., JR., editors, Proceedings of the Tenth Symposium in Applied Mathematics of the American Mathematical Society, Columbia University, April 24–26, 1958, Providence, R. I., American Mathematical Society, 1960, vi + 311 pp. $7.70.

BENSON, O. O., JR., AND STRUGHOLD, H., editors, Physics and medicine of the atmosphere and space (Proceedings of the Second International Symposium on Physics and Medicine of the Atmosphere and Space, San Antonio, Texas, Nov. 10–12, 1958), New York, John Wiley & Sons, Inc., 1960, xviii + 645 pp. $12.50.

BLAND, D. R., Theory of linear viscoelasticity, New York, Pergamon Press, Inc., 1960, vi + 125 pp. $7.50.

BLASZKOWIAK, S., AND KACZKOWSKI, Z., Metoda crossa, Warszawa, Panstwowe Wydawnictwo Naukowe, 1959, 473 pp. zl 87.

BOLEY, B. A., AND WEINER, J. H., Theory of thermal stresses, New York, John Wiley & Sons, Inc., 1960, xv + 586 pp. $15.50.

BRENKERT, K., JR., Elementary theoretical fluid mechanics, New York, John Wiley & Sons, Inc., 1960, xi + 348 pp. $7.50.

CHERNYI, G. G., Flow of gases of at high supersonic speeds [Techeniya gaza s bol'shoi sverkhzukovoi skorost'yu], Moskva, Gosudarstvennoe Izdatel'stvo Fiziko-Matematicheskoi Literatury, 1959, 220 pp. 9 r 20 k.

COLLATZ, L., The numerical treatment of differential equations, 3rd ed., Berlin, Springer-Verlag, 1959, xv + 568 pp. DM 98.

DEVIENNE, F. M., edited by, Rarefied gas dynamics (Proceedings of the First International Symposium, Nice, July 1959), New York, Pergamon Press, Inc., 1960, vi + 442 pp. $17.50.

DOVNOROVICH, V. I., Spatial contact problems in the theory of elasticity [Prostranstvennye Kontaktnye zadachi teorii uprugosti], Minsk, Izdatel'stvo Belorusskogo Gosudarstvennogo Universiteta, 1959, 106 pp. 6 r 65 k.

FIL'CHAKOV, P. F., Theory of filtration in hydraulic structures [Teoriya fil'tratsii pod gidrotekhnicheskimi sooruzheniyami] Vol. 1, Kiev, Izdatel'stvo Akademii Nauk Ukrainskoi SSR, 1959, 308 pp. 12 r.

GRAHAM, L. A., Ingenious mathematical problems and methods, New York, Dover Publications, Inc., 1959, 237 pp. $1.45. (Paperbound)

HENDERSON, F. M., Elliptic functions with complex arguments, Ann Arbor, Michigan, The University of Michigan Press, 1960, v + 38 pp. + charts, $8.

HOHN, F. E., Applied Boolean algebra, New York, The Macmillan Co., 1960, xx + 139 pp. $2.50. (Paperbound)

JACOB, C., Introduction mathematique a la mecanique des fluides, Bucaresti, Institutul de Matematica al Academiei R. P. R., 1959, 1286 pp., Lei 66.50.

KRZYWOBLOCKI, M. Z., Bergman's linear integral operator method in the theory of compressible fluid flow, Wien, Springer-Verlag, 1960, ix + 188 pp. $12.40.

MARINESCU, AL., Teoria Elicopterului, Bucuresti, Editura Academiei Republicii Populare Romine, 1960, 267 pp. Lei 12.60. (Paperbound)

MIKHLIN, S. G., Lectures on linear integral equations [Lektsii po lineinym integral'nym uravneniyam], Moskva, Gosudarstvennoe Izdatel'stvo Fiziko-Matematicheskoi Literatury, 1959, 232 pp. 4 r 45 k.

SCHMIDT, E., Einfuhrung in die Technische Thermodynamik und in die Grundlagen der chemischen Thermodynamik, 8th ed., Berlin, Springer-Verlag, 1960, xx + 543 pp. + tables. DM 33.

STAMPF, W., Der durchlaufende Bogentrager auf elastischen Stutzen mit und ohne Versteifungstrager, Berlin, Springer-Verlag, 1960, viii + 196 pp. DM 37.50.

How to Obtain Copies of Articles Indexed

Photocopy or microfilm copies of articles indexed in this issue will be provided WHENEVER POSSIBLE. Orders should specify the APPLIED MECHANICS REVIEWS volume and review number.

Except as indicated below, address orders to LINDA HALL LIBRARY, 5109 Cherry Street, Kansas City 10, Mo., and include remittance to cover costs. Orders to Linda Hall Library may also be placed by teletype, using the number KC334. Complete copies of the articles reviewed in Referativnyi Zhurnal and reprinted in AMR are received by the editors of AMR or by Linda Hall Library a considerable length of time after publication of the review, and therefore are not immediately available. Photocopy costs are 35¢ for each page of the article photocopied, minimum charge $1.25; microfilm costs include a service charge of 50¢ per article plus 3¢ per double page, minimum charge $1.25. *The applicant assumes responsibility for questions of copyright arising from copying and the use made of copies. Copyright material will not be reproduced beyond recognized "fair use" without consent of the copyright owner.*

To secure copies of reviewed papers from English-translated issues of Russian journals, apply to the English language publisher given in the review heading. Photocopying of such translations is often expressly forbidden. Costs will vary with the publisher.

ENGINEERS everywhere find these ASME technical periodicals unsurpassed in their usefulness. If you are not taking advantage of the help these recognized leaders offer, ASME invites you to do so. Your subscription order should be sent to THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 29 West 39th Street, New York 18, New York.

TRANSACTIONS OF THE ASME

The engineer whose immediate interests are concerned with his highly specialized field will find the essential information he needs in at least one of the following five subdivisions of the ASME Transactions.

Series A—Journal of Engineering for Power publishes significant papers on power generation and usage; conversion of energy sources to power generation; design, operation, and application of gas turbines; fuels; fuel burning equipment; control and utilization of the products of burning processes; hydraulic prime movers; pumping machinery; nuclear engineering; internal combustion engines and auxiliaries; air pollution; solar energy application.

Published in January, April, July, and October.

Series B—Journal of Engineering for Industry contains outstanding contributions on problems encountered in aviation; machine design; process industries; maintenance and plant engineering; management; materials handling; machining and assembly of metal parts, rubber and plastics; areas of the petroleum field; textile machinery; wood industries.

Published in February, May, August, and November.

Series C—Journal of Heat Transfer covers the activities of the field and particularly important problems associated with radiation, conduction, convection, complex systems, phase changes and mixtures, transient phenomena, thermophysical properties, experimental techniques, thermometry, analog methods, analytical and numerical methods, applications, design techniques, heat exchangers, insulation, economic factors, biotechnology, astronautics.

Published in February, May, August, and November.

Series D—Journal of Basic Engineering focuses attention on developments in the following areas: Lubrication; fluid mechanics cavitation; fundamental researches in hydrodynamics; instruments and apparatus; new metals, metal-forming processes, and better engineering application of metals. Research reports on automatic regulation theory, effect of temperature on the properties of metals, mechanical pressure elements, fluid meters, prevention of fracture in metals, plastic flow of metals will also be published in this quarterly.

Published in March, June, September, and December.

Series E—Journal of Applied Mechanics presents fundamental analytical and experimental studies in the fields of elasticity, plasticity, dynamics, vibration, impact, flow and fracture, structures, stress analysis, mechanical properties of materials, hydraulics, aerodynamics, internal flow, turbulence, boundary layers, aeroelasticity, thermodynamics, heat transfer, lubrication and wear, and computing devices and methods. Where subjects overlap the fields covered by the other publications of this Series, the Journal of Applied Mechanics will deal with the basic laws and the more advanced methods of studying problems.

Published in March, June, September, and December.

Annual subscription prices to nonmembers: $10.00 for each Journal, $18.00 for any two, $25.00 for any three, $30.00 for any four, and $33.00 for all five.
To ASME members, prices are 50% less. Additional postage outside the United States and Canada: 50¢ for each Journal.

PMM—JOURNAL OF APPLIED MATHEMATICS AND MECHANICS

This bimonthly contains the important findings of Russian scientists and engineers working in the fields of applied mathematics, fluid and solid mechanics, aeronautical sciences astronautics, rocketry and space flight. It is a cover-to-cover translation of the Journal entitled "Prikladniya Matematika I Mekhanika" which has been for over two decades one of the leading Soviet periodicals in the field. Russian speaking scientists familiar with the subjects are doing most of the translating and every care is being exercised to convey the author's original meaning.

This translation series began with Volume 22 (1958) and is being published bimonthly or corresponding to the number of original Russian issues per annum. All subscriptions are on a calendar year basis.

Annual subscription price: $35.00 to nonmembers, $28.00 to ASME members.

APPLIED MECHANICS REVIEWS

Engineers who read this magazine regularly are able to keep posted on worldwide developments in applied mechanics, both in its established boundaries and wherever it cuts through other fields of scientific and engineering endeavour.

To provide this service and to give readers potentially useful information which might never have come to their attention, AMR's full time editorial staff investigates every known information source, scans the 750 engineering periodicals in 37 countries devoted wholly or in part to the field, all new books containing pertinent information, and the reports of industrial specialists everywhere. The evaluative reviews of the selected material which appear in AMR are prepared and signed by eminently qualified scientists and engineers, many of whom reside in the countries of origin of the magazines from which the articles were taken.

In addition to 500 reviews grouped under the following classifications, each issue of AMR focuses attention on progress and trends in a specialized area.

General: Analytical Methods in Applied Mechanics. Computing Methods and Computers. Analogies. Kinematics, Rigid Dynamics and Oscillations. Instrumentation and Automatic Control. Tables, Charts, Dictionaries, etc.

Mechanics of Solids. Elasticity. Viscoelasticity. Plasticity. Rods, Beams and Strings. Plates, Shells and Membranes. Buckling. Vibrations of Solids. Wave Motion and Impact in Solids. Soil Mechanics: Fundamental and Applied. Processing of Metals and Other Materials. Fracture (Including Fatigue). Experimental Stress Analysis. Material Test Techniques. Properties of Engineering Materials. Structures: Simple and Composite. Machine Elements and Machine Design. Fastening and Joining Methods.

Mechanics of Fluids: Rheology. Hydraulics. Incompressible Flow. Compressible Flow (Continuum and Noncontinuum Flow). Boundary Layer. Turbulence. Aerodynamics. Vibration and Wave Motions in Fluids. Fluid Machinery. Flow and Flight Test Techniques and Measurements.

Heat. Thermodynamics. Heat and Mass Transfer. Combustion. Prime Movers and Propulsion Devices.

Combined Fields and Miscellaneous. Magneto-fluid-dynamics. Aeroelasticity. Aeronautics. Astronautics. Ballistics, Explosions, Acoustics. Micromeritics. Porous Media. Geophysics, Hydrology, Oceanography, Meteorology. Naval Architecture and Marine Engineering. Friction, Lubrication and Wear.

Published monthly. Annual subscription price: $25.00 to nonmembers, $10.00 to ASME members.

MECHANICAL ENGINEERING

This magazine is of prime interest to mechanical engineers regardless of their own specialized line or industry because it gives them the essence of the things that really count in engineering practice . . . . details of processes growing out of concentrated researches, the latest information on improvements in equipment, new materials and new uses of existing materials, application of new methods, improved techniques, the first published reports of significant new developments, creativity, and professional development.

The information is presented in clear, concise and well illustrated articles written by specialists in the fields involved; news items drawn from current engineering periodicals, government reports, and releases of industrial organizations; survey of engineering progress in the British Isles and Western Europe; digests of the hundreds of papers presented at ASME Meetings and Conferences; annotated photographs which transmit useful information on equipment location and arrangement, materials and other engineering tools; letters from readers on a variety of subjects; and comprehensive book reviews.

Published monthly. Annual subscription price: $7.00 to nonmembers. Additional postage outside of U. S. and Canada: $1.50.

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

(Continued on outside back cover)

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)